JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXVIII. JULY, 1884. No. 1

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HOW TO DETERMINE THE GRADE OF EXPANSION

AND THE SIZE OF A STEAM ENGINE WHICH IS TO PERFORM A GIVEN DUTY WITH THE LEAST TOTAL EXPENDITURE OF MONEY PER WORKING HOUR.

By L. D'AURIA.

Denote by

H, the given duty of the engine in horse-powers;
N, number of revolutions per minute;
p_1, absolute initial pressure;
p_2, back pressure, including friction of engine;
V, volume of steam cylinder (unknown);
x, grade of expansion (unknown).

When the ordinary law of expansion is admitted, the two variable quantities V and x are connected by the equation

$$V = \frac{33000\text{H}x}{N\{p_1(1 + \text{hyp. log. } x) - p_2 x\}}.$$

Since H is known, it would seem rather too subtle to establish any relation between the wages to be paid to fireman and engineer, and the variable quantities x or V; at any rate, would be found impracticable. Hence, those items of expense must be entered as constant charges of cost of power. Moreover, if by means of the formula,

$$\text{HP} = \frac{NV\left\{p_1(1 + \text{hyp. log } x) - p_2 x\right\}}{33000x},$$

all other things being given, we determine several values of V corresponding to different grades of expansion x; and afterwards with such data, and the ordinary tables of cylinder condensation, we compute the quantity of steam required in each case, the variations in the latter quantity will be found rather small in comparison with the variations of x and V. Now, since in purchasing a boiler, a liberal allowance is generally made on the steaming capacity strictly necessary to run the engine, it can be seen that from a practical point of view it is not necessary to establish any relation between the capacity of the boiler and the grade of expansion of the engine. It is sufficient to know the duty of the engine in order to fix the capacity of the boiler, upon an assumed low grade of expansion; consequently, all the items of expense due to the cost of boiler, as interest, depreciation of value, and repairs, must also be entered as constant charges of cost of power. We can then represent by a constant K, the sum of wages of fireman and engineer, interest and depreciation of value on cost of boiler, repairs of boiler, all computed per working hour; although such quantity K is different for each particular case.

While a variation in the volume of the steam cylinder can hardly affect the capacity, and, therefore, the cost of boiler, it affects, in a considerable degree, the cost of the engine, which, according to creditable authorities, seems to vary in direct proportion with V. Hence, the items of expense due to the cost of engine, as interest, depreciation of value, repairs, and we may include, also, cost of oil, all computed per working hour, must be expressed by a term AV, where A is to be determined by experience.

Denoting by w the weight per cubic foot of steam of pressure p_1; the theoretical consumption of steam per hour will be

$$\frac{120\,wVN}{x} \text{ lbs.}$$

The percentage of this allowed for condensation and clearance can be expressed by mx^a; m and a, being numbers to be found experimentally. If B is the cost of fuel to make one pound of steam, the actual cost of steam per working hour will be

$$\frac{120\,wBVN(1 + mx^a)}{x};$$

and the total cost of power, will be

$$K + V\left\{A + \frac{120\,wBN(1 + mx^a)}{x}\right\}$$

Now we have

$$\text{Efficiency} = \frac{\text{HP}}{K + V\left\{\dfrac{A + 120wBN(1 + mx^a)}{x}\right\}};$$

and the object of our problem is to make this a maximum with the condition that only V and x are variable quantities. In such case we have

$$\text{der. } V\left\{A + \frac{120\,wBN(1 + mx^a)}{x}\right\} = o,$$

and substituting the value of V in function of x given above, we find

$$\text{der. } \frac{Ax + 120\,wBN(1 + mx^a)}{p_1(1 + \text{hyp. log. } x) - p_2 x} = o.$$

The result of this derivation furnishes the relation

$$\text{hyp. log. } x = \frac{120\,wBN(1 - \frac{p_2}{p_1}x)\,(1 + mx^a - amx^a)}{Ax + 120\,wBNmax^a}$$

which determines the most economical point of cut-off.

In order to make this formula more ready for use, let C represent the cost in dollars and cents of one ton of coal of 2,000 lbs; and n, the number of pounds of water evaporated per pound of coal per hour. We have then

$$B = \frac{C}{2{,}000\,n}$$

and substituting we find

$$\text{hyp. log. } x = \frac{wCN(1 - \frac{p_2}{p_1}x)\,(1 + mx^a - amx^a)}{16{\cdot}666\,nAx + wCNmax^a}. \qquad (1)$$

From Barrus' tables of cylinder condensation for unjacketted factory engines we have deduced $m = 0{\cdot}16$, and $a = \frac{1}{2}$, approximately; hence we can write

$$\text{hyp. log. } x = \frac{wCN(1 - \frac{p_2}{p_1}x)(1 + 0{\cdot}08x^{\frac{1}{2}})}{16{\cdot}666\ nAx + 0{\cdot}08\ wCNx^{\frac{1}{2}}} \qquad (2)$$

Put $C = \$5.00$; $n = 9$ lbs; and assume for a certain style of condensing engine $N = 100$; $p_1 = 90$ lbs; $p_2 = 5$ lbs; $w = 0{\cdot}2092$ found by tables. Suppose that an engine $22'' \times 36''$ of the same style costs \$6,900, and allow 12 per cent. for interest, depreciation of value and repairs; \$0.04 per working hour for oil. We have then

$$AV = \frac{12 \times 6{,}900}{300 \times 10 \times 100} + 0{\cdot}04 = \$0{\cdot}316,$$

and

$$A = \frac{0{\cdot}316}{V} = \frac{0{\cdot}316}{7{\cdot}92} = 0{\cdot}04.$$

Substituting all the above date in equation (2) we find approximately

$$x = 5{\cdot}5$$

Assume $m = o$, in equation (1), that is, no condensation nor clearance, we have

$$\text{hyp. log. } x = \frac{wCN(1 - \frac{p_2}{p_1}x)}{16{\cdot}666nAx}$$

Substituting for w, C, N, n, p_1, p_2 and A, the above values, we find

$$x = 6{\cdot}2;$$

that is an augment of less than 13 per cent. in the grade of expansion, which shows, that considering the amount of condensation given by Barrus' tables as a maximum in practice, any discrepancy between this and the real amount of condensation which may take place in different engines cannot but little affect the most economical point of cut-off determined after equation (2). Hence this equation can be considered as practically correct in all cases, and as such should at once be adopted by engine makers for the pecuniary benefit of their customers and the dignity of the profession.

It remains now with the leading authorities to encourage such adoption by publicly expressing their approval, if the explicitness and correctness of our method warrants it, which we trust.

PRESENT STATE OF THE SUBJECT—"HEAT OF COMBUSTION OF COAL."

By Chief Engineer ISHERWOOD, U. S. Navy.

The experiments of Dulong, Favre, Silbermann, Andrews and other distinguished scientists, have determined the heats of combustion of solid carbon and sulphur, and of hydrogen, olefiant, and marsh gases, within very close limits, the experimental discrepancies being quite inconsiderable. Now the combustible portion of coal is composed of these substances, and did they exist in it in their respective solid and gaseous states, there could be no question that the heat of combustion of coal, as a whole, would be the aggregate of the heats of combustion thus determined of its constituents multiplied by their relative weights. But the hydrogen, olefiant and marsh gases exist in the coal in the solid state, and as they gasify at lower temperatures than their temperatures of ignition, they are, when the coal is subjected to heat, first gasified and afterwards burnt. Now, as some heat is evidently converted into the work of this gasification, the heat of combustion of the coal, as a whole, composed of the aggregate of the heats of combustion of its constituents determined for their respective solid and gaseous states, must be less by that much. The problem is then to ascertain what portion of the heat of combustion of the coal as above determined, is expended in gasifying its volatile constituents; the remaining portion being its proper heat of combustion, that is to say, the heat available for external uses. I am not aware that any direct attempt has ever been made in this direction to solve the problem.

That the heat required to gasify the volatile constituents of coal is small, is evident from an examination of the results of the process of manufacturing illuminating gas. For example: Ordinary dry bituminous coal when retorted for this purpose leaves about 63 per centum of its weight as dry coke, which, sponge-like, rapidly absorbs a considerable amount of moisture from the air. This coke has a much less calorific effect than an equal weight of the coal from which it was derived, owing to its greater percentage of ash, and less percentage of hydrogen, so that the 63 per centum of coke has not more than 60 per centum of the calorific power of the coal from which it was made. Of this coke about three-eighths are consumed in volatilizing the gas from the coal, which makes the gasification cost *commercially* ($\frac{3}{8}$ of

60 =) $22\frac{1}{2}$ per centum of the heat of the coal. Now the temperature of the gases of combustion, which in the furnace is about 2,000 degrees Fahrenheit, is certainly not less than 1,700 degrees after passing the retorts, leaving only 300 degrees expended in gasification, or 15 per centum of the heat in the furnace; hence, of the heat of $22\frac{1}{2}$ per centum of the coal, only 15 per centum is converted into the work of gasification, so that the latter is equivalent to ($22\frac{1}{2} \times \cdot 15 =$) $3\frac{3}{8}$ per centum of the heat of combustion of the coal. For different kinds of coal and different conditions of furnace, these figures will, of course, require corresponding modification, but they are probably nearly correct for the average of practice. Supposing them to be accurate for any given dry coal, then the heat of combustion of that coal can be calculated from the known percentage of its combustible constituents, and from their known respective heats of combustion. It will be the aggregate less $3\frac{3}{8}$ per centum of the sum of the products of these weights by these heats.

The celebrated chemists Dulong and Petit found that in the case of the combustion of cellulose, the heat obtained was only equal to what was due to the solid carbon constituent alone; the remaining constituents being hydrogen and oxygen, in the proportion in which they exist in water, it was assumed that these substances did exist as water in cellulose, the latter being chemically a hydrate of carbon, and that exactly the same quantity of heat was absorbed by their decomposition as was obtained by their recombination. On this hypothesis these chemists based their well known formula that in the combustion of dry vegetable matter (in which hydrogen is always somewhat in excess of what is required to form water with the oxygen) the heat evolved is that due to the carbon constituent and to whatever hydrogen may be in excess after saturating the oxygen constituent. This excess of hydrogen is very small in the case of wood, averaging about seven-tenths of one per centum of the wood. There is no reason for applying this formula to coal, even if it be of vegetable origin, for in that case it has been so changed chemically and physically by time, heat, pressure and its surroundings, that what may have been true of the wood cannot be properly predicted of the coal. Nevertheless, the formula of Dulong does give very close approximations to the total heat of coal, but this is probably owing to the facts:

1st. That the heat of gasification of the volatile constituents of the coal is very small; and

2d. That the weight of the hydrogen constituent of the coal required to saturate the oxygen constituent is also very small.

For example, supposing the hydrogen constituent of bituminous coal to be five per centum and the oxygen constituent eight per centum, then the latter would be saturated by one of the per centums of the hydrogen, leaving four of the per centums to be utilized for heat. Now one of the per centums of the hydrogen thus withdrawn is equal to from three to four per centum of the heat of combustion of the coal calculated from the total heats of its constitutents. But we have already seen that the heat required to gasify the volatile constituents of the coal is also from three to four per centum of the heat of combustion of the coal calculated from the heats of combustion of its constituents and their proportion by weight in the coal. The coincidence is doubtless purely accidental, and does not prove Dulong's law.

It is impossible to conceive that the heat of combustion of coal can be greater than what is due to the sum of the heats of combustion of its constituents multiplied by their proportional weights, less the heat absorbed by the gasification of the volatile constituents. After the gasification has taken place, the heats of combustion of the gases so formed can only be the same as those of the same gases formed in any other manner, and the heat of combustion of the remaining solid carbon must be the same as if it was derived in any other manner.

The subject was in this uncertain state when Messrs. Scheurer-Kestner and Meunier-Dolfus made their celebrated calorimetrical experiments at Thann, in Germany, on the heats of combustion of the Alsatian and other coals, for the Industrial Society of Mulhouse, in Alsace, Germany; and their results, together with a complete description of their apparatus and methods, were published in its well known bulletins. These experiments have a great reputation, and were made by an improved Favre and Silbermann calorimeter with all the corrections and accuracy that the researches of modern science could furnish. The calorimeter employed was tested against that of Favre and Silbermann, by ascertaining with it the heat of combustion of dry charcoal. The Scheurer-Kestner apparatus gave for that heat 8,100 calories, while the Favre apparatus gave 8,080 calories.

From these experiments the startling facts were announced that the heat of combustion of the coals not only exceeded what was due to the formula of Dulong, but that it exceeded considerably the heat of combustion obtained by multiplying the relative weights of the ele-

mentary constituents of the coal by their respective heats of combustion and adding the products together. In other words, the heat of combustion of the coal exceeded the aggregate heat of combustion of its constituents considered as solid carbon and gaseous hydrogen, and exceeded it on an average by about four per centum. If the comparison be made with the heat of combustion due to Dulong's formula, then Scheurer-Kestner's determinations exceed it on an average about nine per centum.

In the calorimetrical experiments of Favre and Silbermann on *organic* substances, the heat of combustion was always found to be less than what was due to that of the constituent carbon and hydrogen. In the single *inorganic* substance of the bisulphide of carbon, the reverse effect was found, and was left unexplained. Berthelot afterwards suggesting that the combination of the sulphur and carbon to form the bisulphide had been attended with absorption of heat, which heat was set free on the decomposition of the substance by combustion. It is remarkable in this connection that, in some calorimetrical experiments on the heat of combustion of three Russian coals, made by Scheurer-Kestner after his experiments with the Alsatian coals, the heat of combustion as found by him averaged $2\frac{2}{3}$ per centum *less* than the heat due to the constituent carbon and hydrogen taken at their full values. These experimental heats averaged almost exactly the heats due to Dulong's formula.

The results of the calorimetrical experiments made by Scheurer-Kestner and Meunier-Dolfus on the heat of combustion of the Alsatian coals, were never accepted by the British scientists, notwithstanding that no error was pointed out in either the apparatus or the method employed. Nor could the writer ever accept them although he bestowed the closest scrutiny and study upon them. He was therefore obliged to defer them until other experiments might be made that would either confirm or overthrow them. Experiments of this kind it appears have been in progress for several years in Munich, Germany, and with results which, though opposed to those of Scheurer-Kestner, are conformable to the general laws of chemistry and to common experience.

As much as is yet known of these later experiments will be found in the following note by Mr. Vinçotte, which I translate from "The Proceedings of the 7th Congress of the Engineers-in-Chief of the Asso-

ciations of the Proprietors of Steam Apparatus," held at Bordeaux, France, in 1882.

The subject is one of much importance to manufactures and commerce, and I have written this communication largely in the hope that the facts may be useful in inducing our government, in consideration of the enormous quantities of coal consumed in this country in the industrial arts, to direct that a commission of properly qualified scientists be appointed to make, together with an ultimate analysis of the coals and of their volatile parts, an exhaustive set of experiments on the heat of combustion of the different coals we produce, and on those of the more important foreign coals with which our own must commercially compete in the near future. Rightly interpreted, these heats of combustion give the relative calorific powers of the coals, and, of course, their respective commercial values.

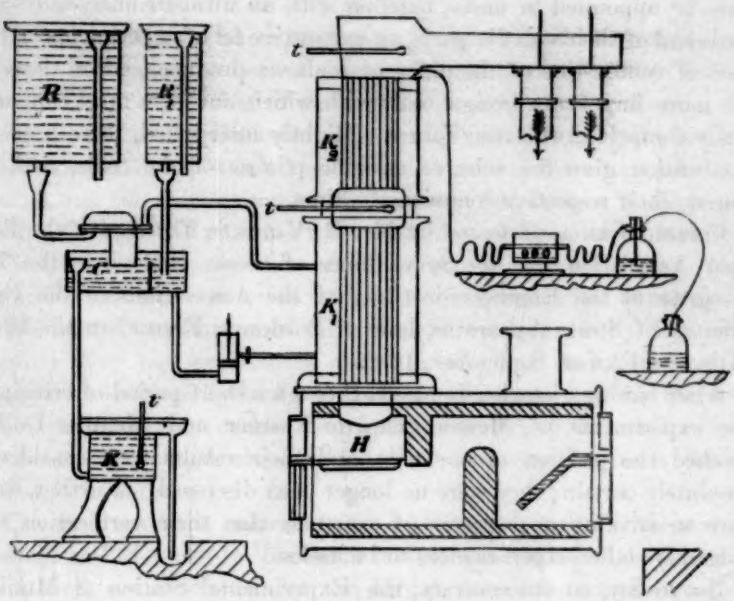
Communication presented by Mr. R. Vinçotte, Director of the Belgian Association for the Surveillance of Steam Boilers, to the 7th Congress of the Engineers-in-Chief of the Associations of the Proprietors of Steam Apparatus, held at Bordeaux, France, on the 10th, 11th, and 12th of September, 1882.

After having victoriously passed through a short period of criticism, the experiments of Messrs. Scheurer-Kestner and Meunier-Dolfus reached the position of a classic, and their results were considered absolutely certain; they were no longer even discussed. Further, they bore so striking a character of exactness that their verification was judged by other experimenters to be useless.

But to-day, on the contrary, the Experimental Station at Munich publishes results which contradict absolutely those of Messrs. Scheurer-Kestner and Meunier-Dolfus, and which I believe will interest the Congress, although I am not in possession of enough of the data of these experiments to enable me to pronounce a positive opinion on them.

The Station at Munich was established by the Bavarian government for the determination of questions relating to heating, for which purpose a boiler was constructed of such design that it could serve as a calorimeter without ceasing to be comparable as a boiler with the boilers employed in factories. It was so arranged that each portion of the heat utilized or lost could be measured separately; and that, at the same time, there could be ascertained the calorific power of a combustible and the distribution of this power in practice by a boiler.

Referring to the accompanying sketch: The furnace H is arrangeable at will for different kinds of combustibles, being adaptable for those giving a long as well as for those giving a short flame. The furnace and its masonry are entirely enclosed in two sheet-iron boxes, one within the other and separated by a water-tight space. The exterior of the outer box is prevented from radiating heat by a lagging of wood. The loss of heat due to the radiation from the masonry is



measured by means of the increased temperature of water circulating between the two sheet-iron boxes.

The hot gases of combustion, on leaving the furnace, traverse in succession two vertical tubular boilers K_1 and K_2, the latter being placed on top of the former. The exterior of both boilers is encased with Hasman's non-conducting covering.

The method of experimenting consists in first heating the apparatus until its temperature becomes stationary. Then the small quantity of ignited coal which remains in the furnace is drawn out, rapidly weighed, and thrown back, and the experiment is began with all the observations made and all the precautions taken requisite in such cases.

The heat radiated from the masonry of the furnace is measured in

the water which constantly circulates between the iron boxes enclosing it, the temperature of the water being noted at its entrance and at its exit.

The loss of heat resulting from exterior radiation, and from the conductibility of the soil on which the furnace rests, is directly measured by heating with steam taken from a locomotive the water between the boxes to a temperature a little higher than what it had during the experiment, and then ascertaining the fall of this temperature during one hour. The loss will be equal to $Q'(t' - t_1')$; Q representing the weight of water between the boxes, and $t^1 - t_1^1$ the fall of temperature.

I ought to say, in reproducing this calculation according to an article by M. Voit, that I do not believe such a process should have been adopted, because it entails a very great error since no account is taken of what the material of the boxes loses or gains at the sides of the furnace. Further, it does not appear at all easy to me to ascertain the exact value of the loss by the furnace due to radiation. The quantity of heat that the smoke abandons in each of the two boilers is measured separately and by the same method.

In the two reservoirs R and R_1 water furnished through lower orifices is kept at a constant level by an overflow, and this water, which is measured in advance, flows into a reservoir C divided into two compartments. The water in the small compartment of C is partly pumped into the boiler, and the remainder overflows into the other compartment.

The steam produced is condensed by the water entering R, and the sum of both, that is the whole quantity of water Q furnished by the two reservoirs, finally enters the calorimeter K where its temperature is measured.

The boiler's loss of heat by exterior radiation is measured directly, and *a priori*, by heating the water in the boiler by means of steam from a locomotive and then measuring the fall of pressure at the end of a given time. The heat usefully absorbed by the second boiler is measured in the same manner.

The gases of combustion are analized by a continuous aspiration across a series of absorption tubes and of a tube containing oxide of copper heated to redness.

The Munich Station commenced operations in 1879, and published in the same year a first series of seventy-six experiments made during the first eight months, which experiments, in my opinion, ought to be

considered as only preparatory for the work to be undertaken. In fact, the results of these experiments are very discordant, and show that great accidental errors are possible with the Munich apparatus. Among them are nineteen determinations of the calorific power of the same coal, so divergent that the extremes differ six per centum from the mean. It is probable that the cause of these errors was discovered, because in a second series of one hundred and sixty-six experiments the different determinations for the same coal gave differences of only one and a half to two per centum. Nevertheless, I must add that, in a vigorous criticism, M. Luders, Professor in the school of Aix-la-Chapelle, points out that in addition to the one hundred and sixty-six experiments published, the second series contained twenty-nine which were rejected without any reason being assigned; and he believes they were omitted because their results differed too greatly from the mean. Be that as it may, I shall not here discuss the value of the methods employed, because I have been able to procure only a part of the publications by the Station. I limit myself therefore to stating the results obtained, according to which the calorific power of the coals is nearly always less than what is due to the formula of Dulong and Petit. The difference is mostly very small, but, in the case of the Louisenthal coal, it rose to ten per centum.

The following table contains the values found:

Name of Coal.	Calorific power in Fahrenheit units of heat.		Name of Coal.	Calorific power in Fahrenheit units of heat.	
	Observed.	Calculat'd by the formula of Dulong.		Observed.	Calculat'd by the formula of Dulong.
St. Ingbert, I *a*.....	13867·2	14365·8	Heinitz-Dechen.....	13402·8	13647·6
" II *a*.....	13077·0	13287·6	Reden-Merchweiler.	12655·8	13174·2
" III *a*.....	12717·0	13123·8	Dudweiler.....	14041·8	14288·4
Mittelbexbach.....	.....	.....	Konig I *a*.....	13114·8	13550·4
Bed No. 3.....	12803·4	12911·4	Friedrichsthal.....	12684·6	12742·2
Bed No. 6.....	12968·4	13444·2	Ziehwald II *a*.....	12110·4	12637·8
Bed No. 9.....	12978·0	13089·6	Louisenthal.....	10940·4	12119·4
Bed No. 10.....	12879·0	12729·6	Griesborn.....	10935·0	10638·0

[*Note by Translator.*—The means of the whole in the above table

shows that the observed calorific powers, or those obtained by experiment, averaged 2·352 per centum less than the calorific powers calculated according to the law of Dulong and Petit.]

The following table compares the calorific powers in Fahrenheit units of heat found by the Station at Munich, and by Messrs. Scheurer-Kestner and Meunier-Dolfus for the same qualities of coal. The figures of the latter gentlemen are for the pure coal, and in order to allow the comparison, I have placed by their side the values calculated according to the law of Dulong and Petit:

	Station at Munich.		Scheurer-Kestner and Meunier-Dolfus.	
	Observed.	Calculated according to Dulong.	Observed.	Calculated according to Dulong.
Dutweiler	14041·8	14288·4	15703·2	14349·6
Heinitz	13402·8	13647·6	15276·6	13714·2
Friedrichsthal	12684·6	12742·2	15222·6	13329·0
Louisenthal	10940·4	12119·4	14787·0	13260·6

The results obtained at the Munich Station were fiercely attacked, and they were declared false because they were in disaccord with those obtained by Messrs. Scheurer-Kestner and Meunier Dolfus. The Munich Station, before these criticisms were made, understood that their first experiments ought to be tested by comparative ones, and they recommenced the determination of the calorific powers of the same coals, requesting M. Stohman, Professor at the University of Leipzig, to make at the same time calorimetrical experiments by the ordinary method.

The results, given in the following table, vary but little, especially if there be taken into consideration the difficulty of obtaining a small sample for the calorimetrical trials, having the same composition as the mean of the coal burnt in the boiler.

M. Stohman in summing up says: You see by our figures that we have found some values in accord with the law of Dulong, and others greatly different, and these last in both directions, sometimes more and sometimes less. We have never found values as high as those of M. Scheurer-Kestner.

These figures suffice to show that if the experiments of Messrs.

Scheurer-Kestner and Meunier-Dolfus are exact, those of the Munich Station cannot be; and, in this connection, I ought to remark that the greatness of the errors necessary to be supposed astonishes me much, but in the absence of sufficient details, I cannot imagine how they could have been made.

Name of Coal.	Calorific Power of the Coal in Fahrenheit units of heat (ash inclusive).			
	Stohman.	Munich Station.	Differences.	
			Absolute.	Per cent.
Dutweiler	15852·8	13674·4	— 178·4	— 1·3
St. Ingbert	13777·2	13721·4	— 55·8	— 0·4
Mittelbexbach No. III	12956·4	12690·0	— 266·4	— 2·0
Louisenthal	12384·0	11970·0	— 414·0	— 3·3
Friedrichsthal	12879·0	12600·0	— 279·0	— 2·1
Thurn and Taxis	12600·0	12297·6	— 302·4	— 3·5
Gehenkinchen (gas making coal)	13302·0	13582·8	+ 280·8	+ 2·0
Gehenkinchen (locomotive coal)	14099·4	14475·6	+ 376·2	+ 1·5
Upper Silesia, Konigsgrube, Sattelflotz	12844·8	12648·6	— 196·2	— 1·5

It appears evident to me at first sight that the Munich apparatus should furnish results more closely concurrent than 12 per centum. Well made experiments on ordinary boilers come closer than that. It seems to me that once familiar with the method of experimenting, figures should be obtained not diverging more than one or two per centum. I have not, however, any reason for rejecting the figures of the second series of experiments: there is no case here of accidental errors. If the general result is erroneous, it must be due to a general error in common for all the experiments. In this connection we encounter in the first place, the determinations of the constants which represent the cooling by radiation from the furnace, from the boilers, and from the calorimetrical apparatus. It seems to me very difficult to determine these constants exactly by the method of cooling during a given time, for the apparatus cannot then be under the conditions of the experiment. It appears to me, therefore, that these constants are strongly subject to inexactness, but, on the other hand, the probable error made under this head is not enough to explain the figures obtained.

Remarks on the above by Mr. E. Cornut, Engineer-in-Chief of the Association of the North of France.

I have had occasion to specially examine the calorimetrical investigations of Messrs. Scheurer-Kestner and Meunier-Dolfus, and, for my part, have the greatest confidence in the results obtained by those able experimenters. I will remark that in a problem of this kind, the errors are in general of two perfectly distinct classes:

1st. A sensibly constant error due to the imperfection of the apparatus and of the methods employed.

2d. Error of observation which, by its very nature, can reach in one direction or the other, such or such an experiment.

This second cause of error does not seem to me to have been in action from a comparison of the results of the calorimetrical powers obtained by the method of Messrs. Scheurer-Kestner and Meunier-Dolfus and those obtained by the German laboratory at Munich; we perceive, in fact, that the case is one of a constant of from about ten to fifteen per centum applying to all the results.

Is there, then, an error of the first category in the experiments at Thann? I will remark that Messrs. Scheurer-Kestner and Meunier-Dolfus took the precaution to test their process by obtaining the calorific power of wood charcoal, and they found its value the same which had been previously ascertained by Messrs. Favre and Silbermann. Have the experimenters at Munich taken that precaution? and, if they have, what figure did they find for the calorific power of wood charcoal?

As our colleague, M. Vinçotte, promises us for the next year more details on this subject, I will leave it for the present; but I believe the experiments of Messrs. Scheurer-Kestner and Meunier-Dolfus to have been made with all possible guarantees for exactness, and in the most disinterested manner.

Low Temperatures.—Wroblewski has tried to measure the temperature of boiling oxygen. For that purpose he applied a system of thermo-electric measurements, which, in addition to being extremely sensitive, may be made to register all the sudden changes in the temperature of the medium. The indications of the apparatus have been compared with those of a hydrogen thermometer, between 100°C. and —130°C. (212°F. and 202°F.) The nature of the function which unites these indications is such as to permit an extrapolation, which indicates —186°C. (—302·8°F.) as a first approximation to the temperature which is produced in the liquifaction of oxygen Compressed nitrogen, at this temperature, solidifies and falls, like snow, in crystals of remarkable size.—*Les Mondes*, Jan. 6, 1884. C.

NEW YORK TO CHICAGO IN SEVENTEEN HOURS.

By W. Barnet LeVan, Engineer.

[Read at the Stated Meeting, May 21, 1884.]

In this paper I propose to show how the distance between New York and Chicago can be covered in seventeen hours, *via* the Pennsylvania and the Pittsburgh, Fort Wayne and Chicago Railroads. The distance by this route is nine hundred and eight miles as follows:

	Miles.		Minutes.
New York City to Philadelphia, Mantua Station	88·26	in	100
Philadelphia to Harrisburg	103·07	in	114
Harrisburg to Altoona	131·6	in	144
Altoona to Pittsburg	116·7	in	128
Pittsburg to Alliance	83	in	91
Alliance to Crestline	106	in	117
Crestline to Fort Wayne	131·39	in	144
Fort Wayne to Chicago	148	in	162
Total miles	907·91		
Total time in minutes			1,000
Crossings at grade in Ohio	16		
" " Indiana	10		
" " Illinois	8		
Total crossings at grade	34		
Time lost in minutes by slowing down according to law			20
Total number of minutes consumed			1,020
Total time of run to Chicago in hours			17

I have selected the Pennsylvania Railroad, as that company controls the shortest and most direct route between the two cities mentioned, and possesses the further advantage of having its tenders fitted with a "pick-up" apparatus for supplying them, while running, with water from troughs placed between the rails.

To accomplish the distance in the time named is with this company only a question of additional safety gates, so as to keep the track clear through the large towns and cities scattered along the route.

I have divided the route up into eight sections, necessitating the use of eight locomotives. This, however, is because of the way the road is divided into Superintendents' Divisions, not from the necessity of changing on account of the locomotives, except on the Western Divi-

sion of the Pennsylvania Railroad, where two locomotives will be required in crossing the Alleghany Mountains.

At Philadelphia, in place of running into Broad Street Station, the locomotive and passenger car, with passengers, will be in waiting at Mantua, and take the place of the locomotive and car of passengers for Philadelphia only. At the other stations on the route the passengers can be changed in the time occupied in changing locomotives.

The ability of the locomotives of the Pennsylvania Railroad Company to perform this journey will be seen by the following indicator diagrams:

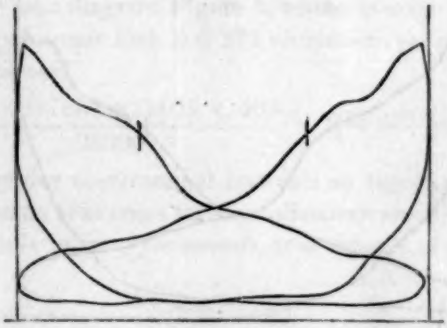


FIG. 1.

Diagram Figure 1 was taken when running at the rate of *fifty-five miles an hour*, cutting off after the piston had traveled seven inches,

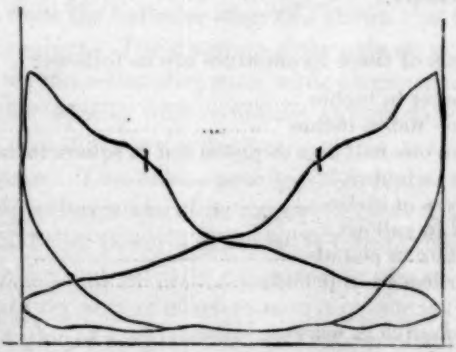


FIG. 2.

with a boiler pressure of one hundred and thirty-five pounds per square inch, an average initial pressure of one hundred and twenty-one and

one-half pounds at commencement of the stroke and eighty-four and one-half pounds at point of cut-off, and eight pounds average back-pressure.

Diagram Figure 2 was taken when running *sixty miles an hour*, cutting off at seven inches, initial pressure one hundred and nineteen and one-half, and eighty-one pounds pressure at point of cut-off, averaging eight and one-half pounds back-pressure.

Diagram Figure 3 was taken when running *sixty-four miles an hour*, boiler pressure as above one hundred and thirty-five pounds per square

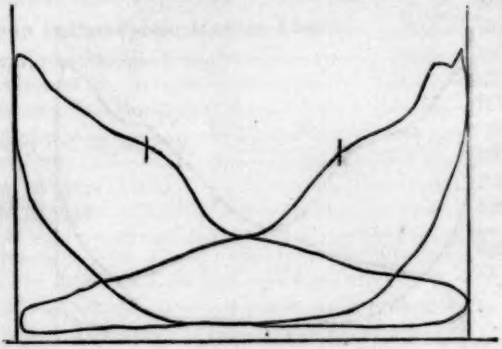


FIG. 3.

inch, initial pressure one hundred and twenty-seven and one-half, and eighty-four pounds at point of cut-off, averaging six and one-quarter pounds back-pressure.

The dimensions of these locomotives are as follows:

Diameter of cylinder in inches	18
Diameter of piston rod in inches	3
Area of piston less one-half area of piston rod in square inches	251
Length of stroke in inches	24
Diameter of drivers in inches	78
Capacity of tank in gallons	1,920
Capacity of coal box in pounds	12,000
Weight of tender loaded in pounds	56,300

Weight of locomotive in working order:

On truck in pounds	27,400
On first pair of drivers in pounds	33,600
On second pair of drivers in pounds	31,700
Total weight in pounds	92,700

The tractive force exerted for each pound of effective pressure per square inch on the piston is as follows:

$$\frac{18^2 \times 24}{78} = \frac{324 \times 24}{78} = 99{\cdot}7 \text{ pounds.}$$

The water tank, as before stated, is fitted with Ramsbottom's water-lifting apparatus for taking in a supply of water while running.

To accomplish 908 miles in seventeen hours the average miles run per hour must be *fifty-five miles*. Therefore, as the locomotive must be able to exceed the average number of miles per hour required for this purpose we will take diagram Figure 3, whose average mean pressure is 40·3 pounds per square inch and 276 revolutions per minute, averaging 677 horse-power.

$$\text{HP} = \frac{18^2 \times 0{\cdot}7854 \times 1104 \times 403}{33000} \times 2 = 677 \text{ horse-power.}$$

It is an every-day occurrence at intervals on the Pennsylvania and Bound Brook route to average for short distances *seventy miles* an hour, in fact, often a mile in *forty-five seconds*, or at the rate of *eighty miles an hour*

$$\frac{60 \times 60}{45} = 80.$$

Therefore, it is not a question of capacity of either the boiler or engines, it is simply a clear track and a disposition of the company to order it done.

It is evident from the indicator diagrams shown that the boilers are superior to the engines. The diagrams show only an average of *sixty-five per cent.* of the theoretical diagrams, while diagrams from stationary engines of similar capacity with automatic cut-off show an average of *ninety per cent.*, this difference is due to the use of the link motion in locomotive engines. The scant opening which it gives when cutting off at *six* to *eight* inches is one of its most prominent defects, as a great part of the actual boiler power is expended in forcing the steam through the narrow openings but partially uncovered by the valve, whereby a loss of over *thirty per cent.* of effective motive power is the result.

By the substitution of a separate cut-off valve similar to that adopted by Mr. A. J. Stevens, of the Central Pacific Railroad, this great loss could be overcome and there would be a great saving of fuel. This substitution would cost about $300 for each engine, and about *thirty-three per cent.* additional working power would be gained by it.

DISCUSSION.

MR. HUGO BILGRAM:—Referring to Mr. Le Van's statement that an independent cut-off will vastly increase the power, I am of opinion that if there were no wire drawing of the steam at all, only a small corner would be added to the diagram, and the power increased by probably less than 10 per cent., instead of 30 per cent. as stated in the paper. The compression would tend to fill up the clearance and prevent the loss of the steam that would otherwise be required to fill the clearance at every stroke.

MR. CYRUS CHAMBERS, JR:—I am of the opinion that it is advantageous to have the excessive back pressure at the termination of the stroke, as shown by the indicator cards, and that it is not detrimental to the power of the engine, provided the compression of the exhaust does not exceed the boiler pressure, because it is utilized in the return stroke giving back to the piston all the power consumed in its compression, less friction and leakage. I agree with Mr. Bilgram on this point.

By closing the exhaust valve just in time to compress the exhaust steam at the end of the stroke up to boiler pressure, the momentum of the moving parts is overcome, all lost motion in the connections are quietly taken up at the point of stroke where the pressures from the induced and exhaust steam are equal on either side of the piston.

This makes a smooth running engine even with considerable lost motion in the connections, and as no steam is taken from the boiler for clearances, but that now in the clearances giving off its power by expansion, I see no loss except from friction and leakage.

My firm has built quite a number of engines compressing the exhaust at the end of stroke to boiler pressure with very satisfactory results.

I do not wish to be understood that we "throttle the exhaust," on the contrary we give a free exhaust until there is just enough exhaust steam left to fill the ports and clearances when compressed to boiler pressure.

We are now constructing an engine in which the terminal pressure of the exhaust (if exhaust it be) is greater than the boiler pressure, and economical results are expected.

MR. HECTOR ORR made an inquiry concerning the safety of such fast running trains as the paper of Mr. Le Van described.

MR. J. W. NYSTROM:—The clearance in locomotive engines is about

that in well constructed stationary engines of the same size, but that is no good reason why the exhaust should be compressed as much as shown on these diagrams. The fact is that when the steam is cut off at an early part of the stroke by link motion, the excessive compression cannot be avoided.

The Porter-Allen engines make very good indicator cards, when running as fast as those on locomotives, showing a proper regulation of steam to and from the cylinder, and the same could be done on locomotives.

I believe Mr. Le Van is right in advocating separate cut-off on locomotives, the accomplishment of which would save at least 20 per cent. in the economy of steam. It has been stated that the economy in excessive compression is due to the saving of clearance steam. The locomotive engines have about 8 per cent. clearance, and when the steam is cut off say at $\frac{1}{4}$ of the stroke, then $\frac{3}{4}$ of the clearance steam is expanded into the cylinder, and the loss is thus two per cent. while the loss of power by compression amounts to 10 or 20 per cent.

In answer to Mr. Orr's question of safety on fast-running trains, I may say that the greatest danger is to run fast on sharp curves, which danger is said to be diminished by a peculiar railroad curve introduced in France by M. Froudé, consisting of a parabola of the third order, and called the *elastic curve*. Engineer C. A. Sundstrom, a member of the Institute, has made the elastic curve a special study, and, I believe, has laid out several of them on the Pennsylvania Railroad. I suggested to Mr. Sundstrom to read a paper on the subject at the Institute on the elastic curve. Mr. Sundstrom says that all the curves on the government railroads in Sweden are elastic curves.

MR. BILGRAM :—In reply to Mr. Nystrom's statement that compression absorbs power, let me say that in expanding engines the greater part of that power would be restored by the consequent re-expansion of the compressed steam. The short and steep compress curve of the diagrams of some engines are due to the very small clearance of such engines, a result which is not attainable on locomotives.

MR. LE VAN :—Messrs. Bilgram and Chambers forget that with link motion, when cutting off at less than half stroke, the initial cylinder pressure does not reach that of the boiler pressure by twenty-five per cent., and only momentarily at that (see Fig. 3), whereas, with an independent cut-off valve, the loss in a well-constructed engine will not be over three per cent. up to point of cut-off.

Take the left hand indicator diagram, Fig. 3, on which I have erected a theoretical diagram (see Fig. 4) from the point of exhaust opening, and represented by the dark shaded portion of the card; this is what would be produced by a perfect engine. Now, in the best practice, with stationary engines of a similar size with our fast locomotives in general use, and running at the same number of revolutions, there are stationary engines that develop *ninety-five per cent.* of the theoretical diagram, whereas diagram, Fig. 3, realizes only *sixty-five per cent.*, a loss of *thirty per cent.*

Now, I maintain that locomotive engine builders can produce just

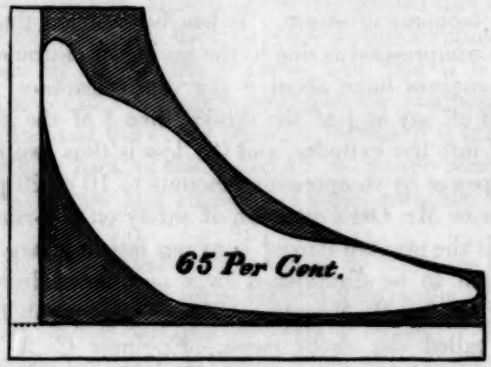


FIG. 4.

as good engines and results as stationary engine builders, and it is incumbent on them to do so.

We all know the difficulties that Mr. Corliss had to contend with when he first introduced his independent cut-off valve; it seemed incredible to those to whom he offered to sell his engine, from the fact they could not understand it, although he explained to them that the efficiency of his engine was due to a higher initial steam pressure in the cylinder, the steam line maintained without expansion, the rapid closing of the steam-valves so that all wire-drawing was prevented and the whole expansion of the steam secured; a low terminal and a free exhaust.

I do not propose to dispense with the link motion, but to add a variable cut-off valve in addition. To many this would seem an unnecessary complication, inasmuch as a separate cut-off valve would be supposed to accomplish quite as much without a link as with it.

It is well known that an engine may be run with an admission of steam to a shorter length of the stroke—in other words, with an earlier cut-off—when an independent variable expansion valve is used, than with the link alone. This being admitted, the question again comes up, "What is the advantage of the link used in addition to the cut off?"

Its advantage is simply as follows:

First.—The link is the simplest and readiest means of reversing.

Second.—While the cut-off is being run at, say, one-fourth or three-eighth stroke, the link may be worked to *vary the exhaust.* It is found to be less advantageous to hold on to the steam as long, when cutting off short, as when following for a greater length of stroke. Let an engine constructed with both a link motion and a separate cut-off valve, have the latter set at one-quarter stroke, the engine meanwhile running along at a corresponding speed; the link, which is supposed to be working the main valve at full throw, may now be pulled up, notch by notch, and it will be found that with each rise of the link and consequent shortening of the throw of the main valve, whereby the exhaust is released earlier and earlier, the engine will quicken its speed.

In the early history of the locomotive the independent cut-off valve as built from designs of Mr. Ethan Rogers, of the Cuyahoga Works, Cleveland, Ohio, and were found to be very efficient. Unfortunately at that time, these improvements were in advance of their time, on account of their additional expense, and the small amount of capital then at command of the railroad companies.

The advantages of independent variable cut-off valves over the ordinary valve controlled by the shifting link motion is well known by the locomotive builders of to-day, but they build a standard locomotive, and can ordinarily sell all they can produce at a fair price, and as long as they have customers for their make they will not change their plan of engines.

Mr. Chambers' statement as to the advantage of compression for overcoming the "jars" or "thumps" due to lost motion of the connected parts is correct, but the amount of compression for this purpose is very much exceeded in indicator diagrams Figs. 1, 2 and 3, thereby causing too great a loss of power.

To Mr. Orr's question of safety, I would say, that in England, where there are one hundred trains running daily, averaging over *fifty miles an hour,* the number of killed is only *one* in 62,000,000 of pas-

sengers carried, and with the improvements now adopted by our railway companies in constructing elastic curves, as stated by Mr. Nystrom, in the place of rigid ones, steel bridges and well-ballasted road-beds, all risks are reduced to a minimum.

ELECTRO-DYNAMICS.

By JOHN W. NYSTROM.

[Read before the Electrical Section of the Franklin Institue, June 13th, 1884.]

The object of this paper is to criticise the electro-dynamics advanced by Count Du Moncel in his work on "Electricity as a Motive Power," page 297, English edition, and to show the confusion in which that subject is yet involved.

The Count Du Moncel gives three formulas on page 299, intended to express the quantity of work accomplished by an electric current, namely as follows:

$$K = RI^2 \qquad 1.$$

$$K = \frac{E^2}{R}. \qquad 2.$$

$$K = EI. \qquad 3.$$

K = work expressed in kilogrammeters.

R = resistence in the conductor expressed in ohms.

I = intensity of current expressed in ampères.

E = electro motive force expressed in volts.

No formulas can express quantity of work without representing the three simple elements—*force, velocity* and *time*, and as the time is wanting in Count Du Moncel's formulas, they cannot express work.

In the simplest formula for work, namely, $K = FS$, or the product of force and space, the time is included in the space S, which is the product of velocity and time. No work can be accomplished without time.

Work is transformed into power by eliminating the time, and the power is thus expressed "work per unit of time," and therefore no work can be transformed into power without dividing it with the time in which it is accomplished, but the Count divides work by the acceleratrix of gravity, and calls the quotient *power*, namely, as follows:

$$P = \frac{RI^2}{g}. \qquad 4.$$

$$P = \frac{E^2}{gR}. \qquad 5.$$

$$P = \frac{EI}{g}. \qquad 6.$$

P = power in effects, which is expressed in kilogrammeters per second.

To divide work with the constant acceleratrix of gravity $g = 9{\cdot}81$ meters per second, which is velocity, will give a quotient of momentum of time FT, when a force F acts for a time T upon a mass free to move. Therefore, the formulas 4, 5 and 6 cannot express power, or the work done per unit of time, when formulas 1, 2 and 3 mean work. It appears that the first three formulas mean *power*, which, multiplied by time T seconds, will give work.

The term *intensity* of current is evidently intended to mean a definite physical quantity, which should have a definite unit of measure, but *intensity* is applied to heat, light, and other phenomena without a definite meaning.

It is evident from the formulas, and also by the mode of measuring *intensity* of current by a galvanometer, that *intensity* means velocity of the electric current, and can, consequently, be expressed by any unit of length per unit of time. *Ampère* is the unit of measure of *intensity* of current, which can be expressed by a unit of velocity. The present value of one *Ampère* is, or should be, a velocity of 1,000 kilometers per second. Therefore, the term *intensity* should be abolished in that connection, and call it what it really is, namely, *velocity* of current, and denote the same with V instead of I, which would make the expression intelligible and definite.

Electromotive force is an expression of a definite physical quantity, which can be measured by any unit of weight, but the unit *volt* does not convey an idea of a definite unit of weight or force. The electromotive force of one *volt* is a weight or force of about one milligram. The term *volt* should therefore be abolished in that connection, and call it what it really is, namely, *milligram*, and the electromotive force should be denoted by F, which means force. These proposed changes would make the subject intelligible and definite, like in mechanics, where we have the well-known physical element *force*, *velocity* and *time*, the combination of which, give the functions *power*, *space* and *work*.

The old and new forms of electro dynamics would compare as follows:

	Old form.		*New form.*	
Power.	$P = \frac{RI^2}{g}$.	1.	$P = V^2$.	1.
	$P = \frac{E^2}{gR}$.	2.	$P = \frac{F^2}{R}$.	2.
	$P = \frac{EI}{g}$.	3.	$P = FV$.	3.
Work.	$K = RI^2$.	4.	$K = RV^2T$.	4.
	$K = \frac{E^2}{R}$.	5.	$K = \frac{F^2T}{R}$.	5.
	$K = EI$.	6.	$K = FVT$.	6.
Resistance.	$R = \frac{E}{I}$.	7.	$R = \frac{F}{V}$.	7.
	$R = \frac{gP}{I^2}$.	8.	$R = \frac{P}{V^2}$	8.
	$R = \frac{E^2}{gP}$.	9.	$R = \frac{F^2}{P}$.	9.
Electro motive force.	$E = RI$.	10.	$F = RV$.	10.
	$E = \sqrt{gRP}$.	11.	$F = \sqrt{PR}$.	11.
	$E = \frac{gP}{I}$.	12.	$F = \frac{P}{V}$.	12.
Velocity of current.	$I = \frac{E}{R}$.	13.	$V = \frac{F}{R}$.	13.
	$I = \sqrt{\frac{gP}{R}}$.	14.	$V = \sqrt{\frac{P}{R}}$.	14.
	$I = \frac{gP}{E}$.	15.	$V = \frac{P}{F}$.	15.
Time of operation in seconds.	$T = \frac{K}{RV^2}$.	16.		
	$T = \frac{KR}{F^2}$.	17.		
	$T = \frac{K}{FV}$.	18.		

P = power in effects, which is expressed by kilogrammeters per second. R = resistance of conductor in ohms.

$E = F$, the electromotive force expressed in milligrams.

$I = V$, the velocity of the electric current in thousands of kilometers per second; that is, when $V = 1$, the velocity is 1,000 kilometers per second.

T = time of operation in seconds. K = work in kilogrammeters.

There are 75 French effects per horse-power.

There is a discrepancy between the old and new formulas for power, which is caused by Count Du Moncel dividing the work by the acceleratrix g, and calls the quotient *power*. Therefore, his formulas for work do not agree with his formulas for *power*.

The new form gives the *power* ten times greater than the old form, on account of the unit of electromotive force is assumed to be one milligram, and the unit of *velocity* 1,000 kilometers per second, which ought to be the units of these quantities.

Comparison of French and English units of power and work.

English.		French.	
Effects P.	Horse-power HP.	Effects P.	Horse power HP.
1	0·001818	0·1382	0·00184
550	1	76·2	1·0136
7·2334	0·00178	1	0·01333
542·47	0·9863	75	1

The numbers which express units of power are equal to the numbers which express units of work done per unit of time, but the quantities, power and work are different from one another, as explained above.

I beg leave to repeat what I have stated many times within the last twenty years, namely, that the science of electricity can never be cleared up before the electrical savants learn to understand dynamics. The greatest difficulty they have to encounter appears to be the distinction between *force, power* and *work*, which quantities they now confound with one another.

The difference between *force, power* and *work* is respectively the same as that between *length, surface* and *volume*.

THE ELLIPTICITY OF PLANETS.

By Pliny Earle Chase, LL. D.

Professor d'Auria's discussion of this subject, in the June number of the Journal of the Franklin Institute, is interesting, not only on account of the amount of terrestrial oblateness which he deduced, but also on account of the discrepancy between the theoretical and the observed values and the evidence, which is thus afforded, that he has not considered all the elements which are involved in the question. This is a common mistake in the theoretical discussion of physical problems. The fact of its existence should teach investigators how unsafe it is to dogmatize upon any results which they may obtain.

Newton (Principia, B. 3, Pr. 19) deduced $\frac{1}{289}$ for the equatorial centrifugal force, and about $\frac{1}{230}$ for the oblateness. The latest estimate of the actual oblateness which has fallen under my notice is Listing's (1878, cited by Newcomb and Holden in their Astronomy, p. 202), 1 : 288·5. This is about twice as great as d'Auria's theoretical value, but it agrees very nearly with Newcomb's estimate of the centrifugal force.

If proper allowance is made for Earth's orbital ellipticity, the harmonic mass-estimate of Sun ÷ Earth (this Journal, May, 1884, p. 356) becomes 329,196, and the Sun's mean distance is 92,542,800 miles. The velocity which would precisely balance the centripetal and centrifugal forces at the equator ($v_1 = \sqrt{gr}$) is 4·90743 miles per second. The actual velocity of rotation, or $v_2 = ·28897$ miles; $v_1 \div v_2 = 16·98$; $(v_1 \div v_2)^2 = 288·4$, which differs by only $\frac{1}{230}$ of one per cent. from Listing's estimate.

The nebular hypothesis connects Neptune, the planet which represents incipient nebular subsidence in the solar system, with Earth, the chief centre of condensation, by the same ratio which connects Earth's equatorial velocity of equilibrium with its velocity of rotation; $329196 \div 16·98 = 19387·3$. Newcomb's estimate is 19380 ± 70. Such closeness of accordance indicates æthereal activities, which are calculated to throw great discredit upon all theories of the retardation of Earth's axial rotation, by "tidal brakes" or by any other influence.

THE DISCHARGE OF TURBINE WATER WHEELS.

By J. P. Frizell

Though it is very desirable to be able to compute with reasonable exactness the quantity of water required by a projected water wheel, this subject is chiefly important in reference to rentals for the use of water. A very simple and reliable method of determining the quantity of water drawn by a lessee consists in determining, once for all, the discharge of his wheels with different openings of gate and different velocities. These results being tabulated afford a ready means of finding the discharge at any time, by observing these elements together with the head acting on the wheel. These results, however, are always obtained experimentally, by measuring the discharge by means of a weir or other known method. No engineer of reputation, to my knowledge, professes to be able to compute the discharge on theoretical grounds.

There is no reason in the nature of things why such a computation cannot be made. The discharge of a wheel is just as clearly determined by its dimensions, head and velocity, as the discharge of a weir is by its dimensions and the depth thereon. Our inability to effect the computation in the former case is due wholly to want of knowledge of the laws of hydraulics.

It has appeared to me that the method of estimating the effect of centrifugal force, given by writers on this subject, has been a great obstacle to the development of a correct theory of the motion of water in a turbine wheel. The nature of the error involved in this method I endeavored to point out in a note printed in the number of this Journal for August, 1883.

An article appears in the May number of this Journal, by Prof. I. P. Church, of Cornell University, in which he maintains, if I understand him, that the expression employed by Weisbach and other writers to represent the effect of centrifugal force in a turbine water wheel is correct, and that the error complained of is verbal rather than real. He supports this view by certain mathematical investigations, and applies the common theory to the computation of the discharge in an experiment upon a turbine in the Tremont Mills, at Lowell, Mass., made by Mr. Francis in 1851, obtaining a result which differs from that of experiment by about 16 per cent. of the latter.

Scientific controversy is probably the most unprofitable employment

of the human mind, and next to that is the exhibition of formulas in hydraulics founded upon imaginary assumptions and hypotheses. I will forbear any comment upon the mathematics of Prof. Church's article, and, accepting the suggestion implied in the above-mentioned computation, will rest the question of the accuracy of my views upon their agreement with the results of the series of experiments referred to. I will consider the experiments with full gate only, taking the turbine as I find it, without any assumption as to its relative dimension, velocity, or the nature of the motion of the water.

I will adopt, so far as necessary, the notation used by Prof. Church, *i. e.*:

Q = volume of water discharged by the wheel.
h = head acting on the wheel.
F = cross section of guide passages at exit.
F_1 = " " wheel " entrance.
F_2 = " " " " exit.
c = velocity through F, c_1 = do. through F_1, c_2 = do. through F_2.
r_1 = radius of wheel at inner ends of floats.
r_2 = do. at outer ends.
ω = angular velocity of wheel.
a = complement of the angle which a tangent to the guide at its extremity makes with a radius to the wheel at the same point.

The inner ends of the floats make substantially a right angle with the inner circumference of the wheel.

The foot and second are the units implied in the above notation.

Aside from the centrifugal force, the general theory of the motion of water in the wheel may be stated very briefly. We suppose the velocity c to be decomposed into its radial and tangential components viz., $c \sin. a$ and $c \cos. a$.

The tangential component is inoperative as regards the discharge.

At the entrance to the wheel there is a loss of head, being the head due the difference between c_1 and the radial component of c, viz.:

$$\frac{1}{2g}(c \sin. a - c_1)^2 = \frac{1}{2g}\left(c \sin. a - c\frac{F}{F_1}\right)^2$$

There is a loss of head due the friction of the water in the supply pipe, and the guide and bucket passages. This might be arrived at by a laborious computation, but as I am not aiming at niceties I will adopt the data given by Wiesbach (Hydraulics Du Bois's trans., p. 359), viz.:

$$\text{Frictional head} = f\frac{c^2}{2g} + f_1\frac{c_2^2}{2g}.$$

Wiesbach says, "We may take $f = f_1 = 0{\cdot}05$ to $0{\cdot}10$." I put, for simplicity,

$$\text{Frictional head} = 0{\cdot}15\,\frac{c^2}{2g},$$

being about the mean given by Wiesbach.

I also adopt Wiesbach's values of the co-efficients of discharge for he guide and bucket orifices. He finds that the cross section of a stream issuing from a straight pipe is about 3 per cent. less than that of the pipe, while a very slight convergence diminishes the stream by 5 per cent. This I adopt.

As soon as the water takes part in the rotary movement of the wheel, it is acted on by a new force, for which (begging Prof. Church's pardon) I can find no better term than "centrifugal force," urging the water *from* the centre of the wheel. The next step is to determine the effect of this force.

Let us fix our attention upon any point, P, in the float curve, at a distance, r, from the centre of the wheel. Let ω_1 represent the angular velocity of the water with reference to the wheel, v its radial velocity. Then the tangential component of the water's absolute motion is represented by $(\omega - \omega_1)\,r$, the radial component by v. By the laws of centrifugal force the former is equivalent to an acceleration of $(\omega - \omega_1)^2\,r$, the latter to an acceleration of $-v$. The centrifugal force, therefore, acting on a mass, M, of water is

$$M\,\{(\omega - \omega_1)^2\,r - v\}$$

We must next find the head due to centrifugal force by determining the work done by the same on a given weight of water in passing through the wheel, and dividing the result by the weight. To do this by forming the polar equation of the float curve, and proceeding according to the strict methods of the calculus, would lead to a hopelessly complex expression. I prefer to resort to the more humble method of approximation by graphical measurement. At P let d represent the angle between the tangent of the float and radius of the wheel, and F_3 the section of the bucket (space between two floats) by a cylindrical surface concentric with the wheel. Then

$$v = c\,\frac{F}{F_3},\ \omega_1 r = v\,\text{tan.}\,d = c\,\frac{F}{F_3}\,\text{tan.}\,d.$$

The expression for centrifugal force then becomes

$$M\left(\omega^2 r - 2\omega c\,\frac{F}{F_3}\,\text{tan.}\,d + c^2\left(\frac{F}{F_3}\right)^2\text{tan.}^2\,d - c\,\frac{F_1}{F_3}\right)$$

Dividing the bucket into any number of parts by concentric cylindrical surfaces, we can compute the coefficients of ω, ω^2, c, c^2 for each part.

By the kindness of Mr. James B. Francis, I have been permitted to examine and measure the original full-size drawings of the wheel, now on file in the office of the Proprietors of the Locks and Canals on Merrimack River, at Lowell, Mass., from which I obtain the following values:

$r_1 = 3{\cdot}375$ ft. $r_2 = 4{\cdot}146$ ft.
$F = 6{\cdot}53$ sq. ft. $F_1 = 19{\cdot}35$ sq. ft. $F_2 = 7{\cdot}467$ sq. ft.
$a = 19°\ 5'$.

From these, together with the several values of d and F_3, I construct the following table:

Radius r. Inches.	Distance from inner edge of crown, measured on radius of wheel. Inches.	F_3 = area of float passage or bucket, measured on cylindrical surface, of radius r, concentric with wheel. Square feet.	$\frac{F'}{44\,F_3}$ = numerical coefficient of c in the expression for the radial velocity.	d = angle between tangent of float and radius of wheel.	$\frac{F'}{44\,F_3}$ tan. d = numerical coefficient of c in the expression for the relative tangential velocity of the water.	Numerical coefficient in the expression for the centrifugal force			
						of ω^2.	of ω.	of c^2.	of c.
41	0·5	0·4397	0·3374	4° 27′	0·0263	3·417	0·0526	0·0002	0·3374
42	1·5	0·4418	0·3359	13° 43′	0·0820	3·500	0·1640	0·0019	0·3359
43	2·5	0·4430	0·3350	23° 20′	0·1445	3·583	0·2890	0·0058	0·3350
44	3·5	0·4460	0·3328	32° 47′	0·2143	3·667	0·4286	0·0125	0·3328
45	4·5	0·4506	0·3294	39° 55′	0·2756	3·750	0·5512	0·0202	0·3294
46	5·5	0·4564	0·3252	48° 37′	0·3691	3·833	0·7382	0·0355	0·3252
47	6·5	0·4639	0·3199	54° 41′	0·4515	3·917	0·9030	0·0520	0·3199
48	7·5	0·4739	0·3132	62° 06′	0·5915	4·000	1·0830	0·0875	0·3132
49	8·5	0·4868	0·3056	69° 38′	0·8232	4·083	1·6464	0·1660	0·3056
49·625	9·125	0·5064	0·2931	77° 18′	1·3006	4·135	2·6012	0·4091	0·2931
49·75	9·25	.....	.....	Extremity 78° 27′					
Sum of the first nine coefficients and ¼ of the 10th.....						34·784	6·5063	0·4839	3·0077
½ of do.....						2·899	0·5422	0·0403	0·2507

The centrifugal force is represented by the expression

$$\left(M = \frac{W}{g}\right)(34{\cdot}784\,\omega^2 - 6{\cdot}5063\,c\omega + 0{\cdot}4839\,c^2 - 3{\cdot}0077\,c),$$

in which M is the mass and W the weight of water included between two consecutive sections one inch apart; $\frac{1}{4}$ the value of the last coefficient is taken because this applies only to $\frac{1}{4}$ inch. The expression may also be understood to represent, in inch-pounds, the work done by centrifugal force on the said mass while passing through the wheel; hence the division by 12 to reduce to foot-pounds. The head due the centrifugal force is represented by

$$\frac{5{\cdot}798\omega^2 - 1{\cdot}0844\omega c + 0{\cdot}0806c^2 - 0{\cdot}5014c}{2g}.$$

This expression in the formula for discharge takes the place of

$$\frac{\omega^2(r_2^2 - r_1^2)}{2g},$$

given generally by writers on the turbine.

The principles stated in what precedes may be expressed algebraically as follows:

$$\frac{c_2^2}{2g} = h - \frac{c^2}{2g}\cos.^2 a - \frac{c^2}{2g}\left(\sin. a - \frac{F}{F_1}\right)^2 - \frac{0{\cdot}15\,c^2}{2g} + \frac{1}{2g}(5{\cdot}798\omega^2 - 1{\cdot}0844\omega c + 0{\cdot}0806c^2 - 0{\cdot}5014c),$$

or

$$\left(c\,\frac{F}{F_2}\right)^2 2gh - c^2\cos.^2 a - c^2\left(\sin. a - \frac{F}{F_1}\right)^2 - 0{\cdot}15c^2 + 5{\cdot}798\omega^2 - 1{\cdot}0844\omega c + 0{\cdot}0806c^2 - 0{\cdot}5014c.$$

Or, substituting numerical values, and reducing

$$1{\cdot}7277c^2 = 2gh + 5{\cdot}798\omega^2 - 1{\cdot}0844\omega c - 0{\cdot}5014c,$$

and

$$Q = 0{\cdot}95Fc.$$

The results given in the following table are computed by this formula. They are arranged according to the ascending values of ω. The table embraces in reality the entire series with full gate, the experiments omitted being substantially nothing more than repetitions of those included:

Number of the experiment in Mr. Francis's series.	n. Number of revolutions of the wheel per second.	$\omega = 2\pi n$. Angular velocity of the wheel. Ft. per sec.	h. Head acting on the wheel. Feet.	Q. Discharge in cub. ft. per sec.	
				By experiment.	By computation.
43	0·	0·	12·797	135·65	134·51
42	0·45431	2·8534	12·948	133·43	133·70
41	0·53232	3·3447	12·977	133·75	134·34
40	0·60000	3·7699	12·973	134·80	134·91
39	0·64702	4·0653	12·963	135·34	135·35
38	0·69471	4·3650	12·944	136·49	135·83
35	0·74211	4·6628	12·939	137·71	136·47
34	0·78401	4·9261	12·941	138·09	137·11
32	0·83624	5·2542	12·915	138·27	137·85
29	0·86643	5·4439	12·906	138·51	138·34
21	0·90201	5·6675	12·889	139·90	138·97
18	0·94507	5·9380	12·880	140·47	139·73
16	0·99945	6·2797	12·890	141·98	140·94
15	1·02373	6·4323	12·888	142·04	141·46
14	1·06744	6·7069	12·856	142·52	142·33
11	1·12518	7·0697	12·819	143·91	143·57
10	1·18460	7·4431	12·800	144·87	145·01
9	1·24514	7·8234	12·777	146·02	146·57
8	1·30933	8·2268	12·720	147·29	148·17
7	1·38249	8·6864	12·696	149·47	150·27
6	1·46149	9·1828	12·653	152·27	152·61
5	1·53218	9·6270	12·611	154·39	154·78
4	1·59051	10·0813	12·554	156·65	156·77
13	1·78404	11·2095	12·510	163·43	163·47

VENTILATION OF SEWERS.—Roger Constantin has presented a note to the French Academy, in which he claims that the health of Paris requires the establishment of ventilating chimneys for the sewers. When the note was read, Dumas stated that while the declivity of the sewers ran from the city towards the river, the air which is heated by contact with the water tends to return towards the centre of the city through the entrances of the sewers. Constantin proposed four large chimneys at the lower openings of the sewers, carried to a sufficient height to preserve the city from all infection. Berthelot thought it indispensable that the deleterious gases should be burned by passing through a fire. Casalonga suggests that it would be better to place the ventilating chimneys at the upper rather than at the lower part of the sewers.—*Chron. Industr.*, Oct. 7, 1883. C.

THE IRIDIUM INDUSTRY.

By Wm. L. Dudley, Cincinnati, O.

[Read at the Cincinnati Meeting, American Institute of Mining Engineers, Feb., 1884.]

It is my desire to call attention to a new industry which was started about four years ago, through the discovery by Mr. John Holland, a resident of this city, of methods suitable for working the metal iridium. This metal has been known since the year 1803, having been discovered by Smithson Tennant while investigating the metallic residue which remained when platinum ores were dissolved in aqua regia. The metal is classed among the rare metals, as it is not found in large quantities, although it is quite widely distributed geographically. It is found in California, Oregon, Russia, East India, Borneo, South America, Canada, Australia, and in certain parts of France, Germany, and Spain. The principal sources of supply of the metal are Russia and California; it is nearly always found with either platinum or gold, is extracted from those ores as a by-product, and is always found in small grains or fine powder, the largest pieces being about the size of a grain of rice. In nature it is generally alloyed with other metals, and the two metals with which it is most commonly alloyed are platinum and osmium; the platinum alloy is called platin-iridium, and the osmium alloy osmiridium, or iridosmine. The grains of platin-iridium are sometimes found as small cubes with rounded edges, while the iridosmine usually exists in the form of flat irregular grains and occasionally as hexagonal prisms. The supply of metal which is derived from Russia is generally obtained from the platinum mines which are situated in the Ural Mountains; while in California it is found principally in the placer gold-washings. The ores of iridium are a source of great annoyance when mixed with gold-dust on account of its specific gravity, which is about 19·3, being nearly the same as that of gold. Consequently, it is impossible to separate the gold from the iridium by the process of washing; the separation may, however, be made either by the amalgamation of the gold (as neither iridium nor its ores combine with mercury), or by dissolving out the gold in aqua regia.

In the mints these metals are frequently separated by melting the gold-dust and allowing the molten mass to remain in the crucible for some time, during which the iridium slowly settles to the bottom as it

does not alloy with the gold under such circumstances. The gold is then poured off from the top, and the dregs in the bottom of the crucible are found to contain the greater quantity of the iridium. The gold contained in the dregs is then dissolved and the iridium is found in the residue.

In Russia it is contrary to the law to possess or deal in iridium ore, and, consequently, the government takes possession of all the ore which is mined or extracted from the platinum ores in that country, and it is stored in the vaults of the Royal Mint. The reason for the law is, that some years ago the Russian government found that speculators in gold-dust would sometimes add iridium to it (which often escaped detection by the officials of the mint), for the purpose of increasing its weight. On attempting to work this gold they found the fine particles of iridium distributed through the ingots; on rolling the ingots into sheets, these individual grains or particles produced indentations in their steel rolls; and in striking out the coins the dies were marred and defaced thus causing considerable loss to the government. In order to prevent this species of fraud, the government passed a law prohibiting persons from handling the metal in any way and compelling its immediate surrender.

For a number of years experimenters have endeavored to melt the iridosmine or iridium in order to utilize it in the arts for such purposes as could with advantage employ a metal of its wonderful properties; but until lately success has been only partial.

I may here briefly describe the properties of the metal itself. Iridium possesses a white lustre, resembling that of steel; its hardness is about equal to that of the ruby; in the cold it is quite brittle, but at a white heat it is somewhat malleable. It is one of the heaviest of metals, having a specific gravity af 22·38. When heated in the air to a red heat the metal is very slowly oxidized; but upon raising the temperature to about 1,000 C., it parts with its oxygen, and hence at a high heat (above 1,000 C.), it is not oxidized. It is insoluble in all single acids, but is very slightly soluble in aqua regia after being heated in the state of fine powder for many hours. In a massive state, however, aqua regia does not attack it.

In attempting to fuse iridium heretofore, it has been found by experimenters that the best results that could be obtained were by means of the oxy-hydrogen or electric furnaces, but that with either of these means of fusion they could only work a very small quantity of the

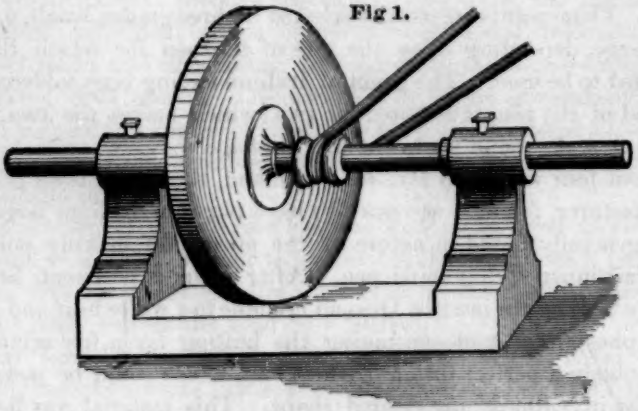
metal at a time, and obtain a globule of very small size. Previous to the present time iridium has had substantially but one use (with the exception of alloying with platinum), viz., for pointing gold pens. The iridium point is commonly called "diamond point" upon a gold pen, and it consists simply of a small grain of iridosmine which has been selected for the purpose, and soldered to the tip of the pen. These are selected by first removing from the ore, with a magnet, the magnetic oxide of iron which always accompanies it, and then dissolving out, by means of acids, the other impurities which may be present; the ore is then washed with water, dried and sifted in order to remove the fine dust, and the sifted ore is then ready for the selection of points. This is done by an operator, who rolls the grains of iridium around with a needle point, examining them under a magnifying glass, and selecting those which are solid, compact, and of the proper size and shape. These points are usually selected in three grades, small, medium, and large, depending upon the size of the pen for which they are intended to be used. The grain of iridium having been soldered on to the end of the pen, it is sawed in two (which makes the two nibs of the pen), and ground up in the proper shape.

About four years ago Mr. John Holland, the well known gold pen manufacturer, found it necessary to have pieces of iridium larger than those generally found in nature for the purpose of making points for the Mackinnon stylographic pen. After many experiments he found that by heating the ore in a Hessian crucible to a white heat and adding to it phosphorus, and continuing the heating for a few minutes, he could obtain a perfect fusion of the metal, which could be poured out and cast into almost any desired shape. This material was found on physical examination to be about as hard as the natural grains of iridium; and in fact seemed to have all the properties of the metal itself. On chemical analysis it was found that the metal fused with phosphorus contained, according to two determinations, 7·52 per cent. and 7·74 per cent. of phosphorus. At this stage of the discovery we became acquainted with it, and began experiments with the intention of putting the product to some practical use in the arts. It was found that the presence of phosphorus rendered the metal quite readily fusible at a white heat, but this, of course, was an obstacle in the way of its use for electrical purposes. Desiring, therefore, to remove the phosphorus, we found by experimenting that by heating the metal in a bed of lime the phosphorus could be completely removed. In this operation, the

metal is first heated in an ordinary furnace to a white heat, and finally, after no more phosphorus makes its appearance, it is removed and placed in an electric furnace with a lime crucible and there heated until the last traces of phosphorus are removed; the metal which then remains will resist as much heat without fusion as the native metal.

In mechanical applications, where the metal is not subject to great heat, it is melted with phosphorus and cast into the shape desired, and then ground or worked as the application may require. The first application to which it was put was for the manufacture of the Mackinnon pen-points. For this purpose, the metal, after being fused, is removed from the furnace and poured between two slabs of iron which are kept apart the desired distance so as to make a sheet of iridium of

Fig 1.



the thickness required. The metal is poured, as I have said, between these plates, and the plates are brought suddenly together, on the plan of a closed ingot with a hinge, so that as the metal cools it is subjected to pressure which closes the pores and makes a very compact casting. The slabs for the Mackinnon pen-points are about one thirty-second of an inch in thickness, and are broken up into small irregular pieces which are soldered on a strip of brass and ground down to a flat surface by means of a copper-lap. The copper-lap (Fig. 1) consists of a plate of copper, about one-half inch in thickness and eight inches in diameter, fixed on a spindle which is made to revolve from eight hundred to a thousand revolutions per minute; the copper of which the lap is composed is wrought copper, well annealed, and consequently

very soft. In order to grind with it, corundum or diamond-dust is mixed with oil and applied to the flat surface of the lap by means of a flat steel instrument, upon which pressure is applied in order to force the corundum or diamond-dust into the copper, thereby making a cutting surface. The irridum to be ground is held against this sharp surface of the lap, and the corundum or diamond-dust gradually cuts the metal away. As the cutting material wears from the copper-lap, another application of the corundum and diamond-dust is made by

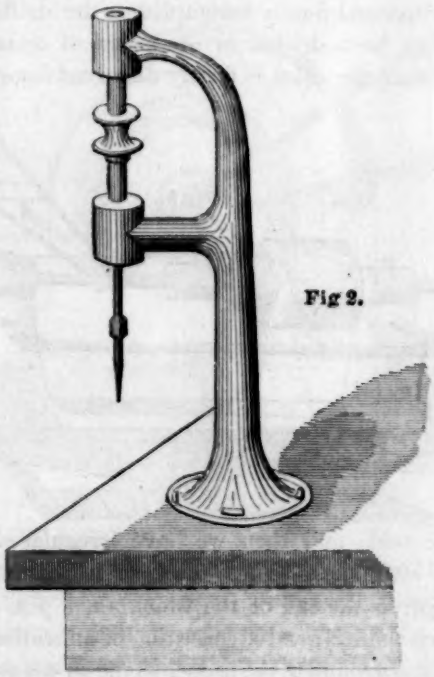
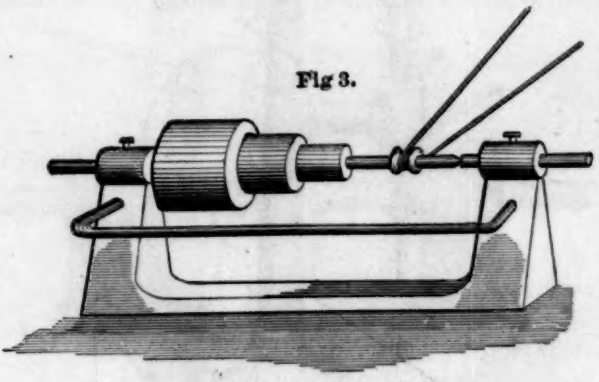


Fig 2.

means of the steel instrument as described; this operation is continued until the grinding is complete. After the slabs are ground to a surface they are then drilled. In the drilling operation, the iridium is first countersunk by means of a diamond drill, consisting of an upright spindle suitably fixed in a frame so as to revolve freely; the bottom of the spindle holds a small rod of brass, to the lower end of which is set a white diamond-splint. This drill is made to revolve about nine hundred revolutions per minute. The iridium is held up against the

diamond with a light pressure, and the diamond gradually makes a conical hole or countersink. After countersinking the iridium, it is finally pierced by means of a copper drill (Fig. 2), which consists of a piece of soft copper wire, which is filed down to a point and set in a drill similar to that in which the diamond is placed, but this drill makes about thirty-five hundred revolutions per minute. Corundum or diamond-dust and oil is put into the countersink opening in the iridium, and then it is held up against the piece of revolving copper. The diamond-dust or corundum, imbedding itself in the copper, acts as a cutting surface, and finally accomplishes the drilling of the hole. The holes having been drilled in the pieces of iridum which were soldered to the brass, the brass is finally dissolved from the iridium by

Fig 3.



means of nitric acid; and then we have irregular-shaped pieces of iridium, pierced with holes. These pieces of iridium are then soldered in proper position to the end of the Mackinnon pen, fitting into the opening of which there is a valve consisting of an iridium-pointed wire. The iridium is then ground to the proper shape on the outside by means of a copper-lap, as shown in (Fig. 3), consisting of three or more copper cylinders on a common spindle, making about three thousand revolutions per minute.

The operation of sawing iridium is carried on by means of a copper disk (Fig. 4), from four to eight inches in diameter, made of soft thin sheet-copper, held between two clamps, placed on a spindle revolving at the rate of about twenty-five hundred revolutions per minute. This sheet of copper revolves in a box which contains corundum or diamond-dust and cotton-seed oil. The cotton-seed oil with the cut-

ting material adheres to the periphery of the saw, and as the saw comes in contact with a piece of iridium it gradually does the work. Cotton-seed oil is preferred for this purpose to any other oil, on account of its viscosity.

I may mention briefly some of the uses to which iridium has been applied. First, I will refer to the draw-plate for drawing wire. There are at present, besides the iridium draw-plate, the ordinary steel plate which is used for drawing heavy wire, and the ruby plate, which is used in drawing gold and silver wires, where it is desirable to have

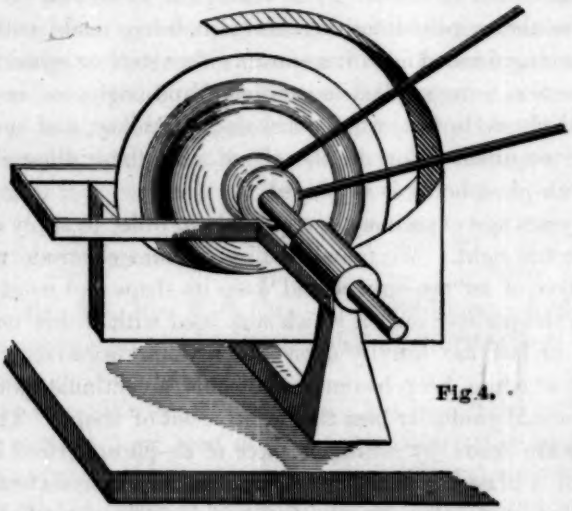


Fig 4.

them of uniform thickness. The iridium plate is made somewhat similar to the ruby plate, consisting of a piece of iridium which has been countersunk and drilled in the usual way to the size of the hole required, and set in a brass plate, where it is firmly held by a bushing. This plate is now coming into use, and is rapidly taking the place of the ruby plate, being equal to the ruby in hardness and much more durable, since it is less liable to break or chip by rough handling or heating.

Iridium knives are made for fine scales and balances, the bearing edge of which consists of iridium, soldered firmly to a brass body. These are rapidly taking the place of the agate for fine chemical balances, and there seems to be no reason why they should not have even a more extended use, since they are superior to the agate in that

they take a finer edge and thereby make a more delicate balance, and are not so liable to crack or break. They are now being used altogether by Mr. Henry Troemner, of Philadelphia, the well-known scale manufacturer, for the purpose of adjusting his weights for all of his scales.

Hypodermic needles for physicians' and surgeons' use are now made of gold and tipped with iridium, in place of the old steel pointed ones, which are liable to rust or corrode if not properly taken care of. The iridium being hard will take a good edge, and is not subject to corrosion, as is steel.

Styluses for manifold writing are also being made with iridium points, having decided advantages over either steel or agate. Iridium points are also being applied to surveyors' and engineers' instruments, and in all places, in fact, where hardness, durability, and non-corrosibility are required. For all the above uses the iridium alloyed by fusion with phosphorus is employed.

Some years ago experiments were made in order to apply this metal to the electric light. We found that an iridium electrode used upon the negative of an arc-light would keep its shape and resist the heat, provided the positive carbon which was used with it was not allowed to strike or fall too heavily upon the iridium negative. Since the metal at a white heat becomes malleable, a continual pounding or striking would gradually beat the negative out of shape. The iridium negatives are made by setting a piece of de-phosphorized iridium in the end of a brass rod about six inches long and nine-sixteenths of an inch in diameter. The length of the iridium is about half an inch, ground conical in shape. It was found that the brass, being only half an inch from the arc, would resist the action of the heat; but in some cases where the lamp flamed the brass was liable to undergo partial fusion; and in such cases it was found desirable to put a thimble or cap of platinum over the end of the brass and just below the iridium, the platinum thimble being about half an inch long.

One of the most important applications of iridium which has yet been made is to the electrical contact-points of telegraphic apparatus. These contact-points consist of pieces of copper wire tipped with iridium, which are set in the instrument just as platinum points are set. These contacts will outlive many platinum contacts; are not subject to oxidization or sticking as are the platinum ones; and all that is necessary in order to clean them when they become dirty is to pass over

their surface an emery file or a piece of fine emery-paper. These contacts have been thoroughly tested by various eminent electricians and also by long continued use, and the advantages herein stated have been in every case fully demonstrated.

In the past three years we have been experimenting on methods of plating with iridium, and about one year ago we succeeded in obtaining a bright reguline deposit of iridium on base metals. This deposit resembles the natural metal, being quite hard and resisting the action of acids. There were many difficulties encountered in accomplishing this result, on account of the power of the metal to resist the action of the solvents; but we have succeeded in obtaining a solution which gradually attacks an anode of iridium, and it is hoped in a short time that all the minor practical difficulties will be overcome in the plating of articles on a commercial scale. So far, we have been thoroughly testing our results, and do not feel prepared to place our work before the public until it is perfect in all its details.

DISCUSSION.

JAMES C. BAYLES, New York City:—I would like to ask Mr. Dudley how the anode is prepared in electro-plating; whether from iridium in grains, or in the fused state.

MR. DUDLEY:—We use iridium which has been fused with phosphorus. It contains 5 per cent. of phosphorus, which does no damage. Of course, in working out a problem of this nature, it takes several years to ascertain all the causes of disturbance; but we have not yet attributed any trouble to the phosphorus in the solution. We have made many experiments with alloys of iridium, but have practically failed to get an anode of them which would readily dissolve; but we find that the anode of fused iridium gradually dissolves, and yet not fast enough to keep the solution replenished, without the addition, now and then, of some of the pure salt, the amount depending upon the kind of solution employed. The same thing is necessary in silver, and in nickel-plating. Theoretically, the anode should dissolve and keep the solution up to the proper strength. In practice, that is never the case.

MR. BAYLES:—How is the solution made?

MR. DUDLEY:—This solution is made by dissolving the iridium first with chlorine and sodium chloride. The iridium or iridosmine is mixed with common salt, placed in a tube, and heated to redness. Chlorine gas is then allowed to flow slowly through the tube for several

hours, at the end of which time most of the iridium will have combined with the salt and chlorine to form the double chloride of iridium and sodium, which rapidly dissolves in water. From this solution we can obtain any salt of iridium which we desire. In plating with the metal, we find that a solution, very slightly acidified with sulphuric acids, gives the best results practically, although neutral or alkaline solutions work very well.

A MEMBER:—What kind of solder is used in soldering iridium to other metals?

MR. DUDLEY:—Ordinary silver-solder. Soft solder will solder the metal as well, but we seldom use it, since it is not as durable.

DR. R. W. RAYMOND, New York City:—I would ask whether it is known what is the possible supply of that metal.

MR. DUDLEY:—Well, we find it, like a good many other metals, widely distributed—in Canada, and many parts of the United States, in France, and a great many European countries, and, as I have said, the largest supply has heretofore been in Russia. The Russian government is very arbitrary, and they enforce their laws right up to the mark, and generally when they make a law, they make it pretty strong to start with. (Laughter.) As iridium was found principally in Russia, we sent over a representative to see what could be done about getting our supply from there. He went to the United States consul at St. Petersburg, and was informed that there was a law, requiring persons who had any iridium in their possession, to turn it over immediately to the authorities, on pain of being exiled to Siberia for life. (Laughter.) The result was that, in a short time, the mint had stored up in its vaults quite a supply of the metal. Our representative went to the Consul, who telegraphed to the platinum mines, where most of the iridium is obtained, but received no answer. He wrote a letter, but still no answer. Telegraphed again. No answer. He finally found that as every telegram of communication was liable to be opened and read, those receiving the same were afraid to have anything to do with the matter for fear of going to Siberia. The result was that he could do nothing. But there are some parties in Hamburg, who deal in the ore, and we get most of it from them. It is said that they get it from the mint at St. Petersburg. I may say, also, that we get from three to four hundred ounces annually from the United States government. We do not get more for the reason that the mints will not knowingly buy gold-dust which contains any iridium. They examine the dust very carefully, but, in spite of their care, they get a little.

PHYSICAL AND CHEMICAL TESTS OF STEEL FOR BOILER- AND SHIP-PLATE FOR THE UNITED STATES GOVERNMENT CRUISERS.*

By PEDRO G. SALOM,

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I have had an opportunity, within the last few months, of making a large number of physical and chemical tests of steel for boiler and ship-plate, which has been, and is used principally for the United States Government cruisers, now building in Mr. John Roach's yard, at Chester, Pa. Through the courtesy of the Messrs. Houston, of the Chester Rolling Mills, I have the honor to lay before the members of the Institute the results of these tests. These results have developed some points in regard to the nature of steel, which are more or less new, and which, I hope, will prove interesting.

The original specifications, as regards the *manner* of testing, were so impracticable (when their severity was taken into consideration), that the keel of the first vessel, which will be launched next month, would, had they been carried out, probably not have been laid until next year. At my suggestion, in order to simplify and expedite the immense amount of testing that had to be done, the Naval Advisory Board was induced, after considerable discussion, to alter the specifications, so as to test each heat, instead of each lot of twenty plates, but reserved the right of making the quenching-test on a piece from each ingot, after it had been rolled.

This relieved us from the anxiety of having a lot of plates rejected, after they had been rolled and sheared, by reason of the presence of one or two plates, which might have been injured in heating or rolling, or which might not have been able to stand the tests, while it insured the Government in obtaining a uniform quality of steel, and prevented the temptation to introduce a half-dozen or more bad plates in a lot, and run the risk of their being selected as the test-plates.

I give below a portion of the original specifications, as prescribed by the Naval Advisory Board, in order to insure the fulfillment of the clause of the Act of Congress of August 5, 1882: "Such vessels . . . .

* Read at the Cincinnati Meeting, American Institute of Mining Engineers, February, 1884.

to be constructed of steel, of domestic manufacture, having, as near as may be, a tensile strength of not less than sixty thousand pounds to the square inch, and a ductility in eight inches of not less than twenty-five per centum."

RULE III.—In every lot of twenty plates, test-pieces to be cut from two plates taken at random; two test-pieces being cut from each plate,—one in the direction of the rolling, and one at right angles to it, shaped according to the annexed sketch. These test-pieces shall in no case be annealed.

The test-pieces to be submitted to a direct tensile stress, until they break and in a machine of approved character.

The initial stress to be as near the elastic limit as possible, which limit is to be carefully determined by the inspector in a special series of tests. The first load to be kept in continuous action for five minutes. Additional loads to be then added at intervals of time, as nearly as possible equal, and separated by half a minute; the loads to produce a strain of 5,000 pounds per square inch of original section of the test-piece, until the stress is about 50,000 pounds per square inch of original section, when the additional loads should be in increments not exceeding 1,000 pounds.

An observation to be made of the corresponding elongation measured upon the original length of eight inches.

Conditions of Acceptance.—In order to be accepted, the average of the four test-pieces must show an ultimate tensile strength of at least 60,000 pounds per square inch of original section, and a final elongation in eight inches of not less than 25 per cent.

Lots of material, which show a strength greater than 60,000 pounds per square inch, will be accepted, providing the ductility remains at least 23 per cent.

Cases of Failure,—If the average of these four test-pieces, numbered 1, 2, 3, 4 (called Test I), fall below either of the required limits, the plates, from which pieces 1, 2, 3, 4 were cut, shall be rejected, and Test II made, consisting of pieces 5 and 6, cut from a third plate. If the mean of the results of these two fall below either of the above limits, the entire lot shall be rejected. If it be successful, Test III, or the mean of pieces 7 and 8 cut from a fourth plate, shall decide.

If, in any of Tests I, II, III, any single piece shows a tensile strength less than 58,000 pounds, or a final elongation less than 21 per cent., the plate, from which it was cut, shall be rejected, and that Test considered to have failed, regardless of its average.

RULE IV.—*Quenching Test.*—A test-piece shall be cut from *each* plate, angle or beam, and, after heating it to a cherry-red, plunged in water at a temperature of 82°F. Thus prepared, it must be possible to bend the pieces under a press or hammer, so that they shall be doubled round a curve, of which the diameter is not less than one and a half times the thickness of the plates tested, without presenting any trace of cracking.

These test-pieces must not have their sheared sides rounded off; the only treatment permitted being taking off the sharpness of the edges with a fine file.

RULE VII.—*Each* boiler-plate must be subjected to the same tests, and in the manner prescribed for ship-plates. The ductility in eight inches must not be less than 25 per cent., and the ultimate tensile strength must not be less than 57,000 pounds, and not more than 63,000 pounds, and the average, at least, 60,000 pounds.

The following diagrams represent, Fig. 1, the 8-inch and Fig. 2, the 1-inch test-piece. The tests were made on an improved 100,000 pound Riehlé hydraulic machine.

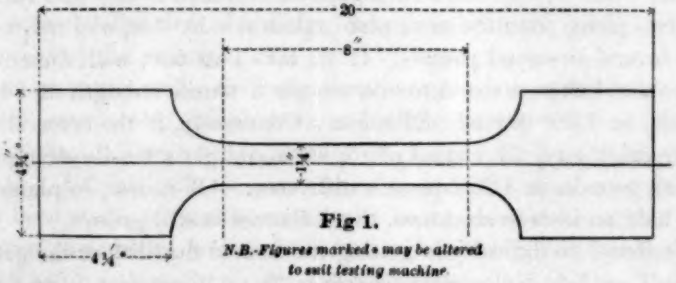


Fig 1.

N.B.-Figures marked may be altered to suit testing machine.

In the original specifications, it will be observed by reference to the above rules, that plates of only 58,000 pounds tensile strength, might pass, provided the average of all the test-pieces was 60,000 pounds, or over; but, in the amended specifications we were not granted even this

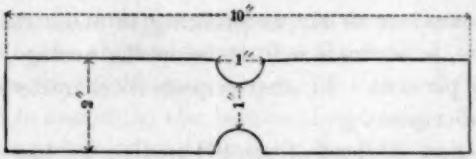


Fig 2.

little piece of grace, and, unless the average of the two test pieces, selected from each heat, was 60,000 pounds or over, and 23 per cent. stretch or over (and in neither test to fall below 58,000 pounds, or 21 per cent.), the heat was rejected. In other words, to take a practical example, if two test-pieces from the same heat gave 59,900 pounds tensile strength, with the required elongation, the heat was rejected. If, however, one of those pieces gave 58,000 pounds, and the other 62,000 pounds, with other conditions remaining the same, the heat was accepted.

To give some idea of the manner in which the inspection was first conducted, I refer to heat 435 in the accompanying table. Here the tensile strength was 56,900, instead of 57,000 (for boiler-plate), with a splendid elongation of 28 per cent.; yet, notwithstanding this fact, the heat was rejected, and we were not allowed to roll that metal for the cruisers. This, also, in view of the well-known fact that the difference of the $\frac{1}{100}$ of an inch in taking measurements of test-pieces makes a difference of 1,200 pounds to the square inch in a half-inch section,—that is, a section from a plate half an inch thick; and further, that two pieces from the same plate, taken side by side, will frequently vary several thousand pounds. If we take heat 500, with dimensions $1 \times \cdot 5$, and change the ·5 to ·49, we get a tensile strength of 64,300 pounds, or 1,300 pounds difference. Conversely, if the error should be the other way, ·51 instead of ·5, we would get a tensile strength of 61,800 pounds, or 1,200 pounds difference. Of course, in plates less than half an inch in thickness, the difference is still greater.

We found no difficulty in getting the desired ductility or elongation, since all our best boiler-plate gives from 28 to 30 per cent. in an 8-inch section; but the trouble came in getting the tensile strength to run over 60,000 pounds, and maintaining at the same time the very high percentage of elongation required. This difficulty was finally overcome, and we were able to meet the specifications with gratifying regularity.

Heat 453 (see table) is inserted to show the character of steel we were making previous to our undertaking to make the cruiser-steel. The manganese, however, is a little below the average, which should be about 0·25 per cent. In other respects its characteristics are those of the best boiler-plate.

Out of the first 33 heats, from 464 to 496, we lost 14, or 42 per cent. Only four of these heats, however, could be called inferior; the remaining ten being, in my opinion, better material than that accepted. In the next 100 heats only 10 failed to pass the specifications. Nine of these were condemned on account of being too soft, only one (No. 525) for being too hard, *i. e.*, not giving the required stretch. It would have been possible to secure a still lower percentage of condemned heats; but we did not care to risk making metal like No. 525, and preferred to fail occasionally by making it too soft, since this metal, when rejected, we could use for the best flange and fire-box plate. In the last 47 heats only three failed to come up to the specifications. No. 602 we did not test, and No. 604 was lost.

The first hundred heats, from No 464 to No. 563, in addition to the usual amount of pig iron, scrap, and shearings, contained charcoal-blooms and muck-bar (gradually increased amounts of muck-bar and a corresponding diminution of blooms, which were at first charged in equal amounts.) Nos. 564 to 619, were all made from muck-bar, with results equally if not more satisfactory than with blooms. Of the remaining heats, a few were made from all blooms, a few from all muck-bar, and the others from a mixture of the two.

The tests marked with an asterisk were made on pieces cut at right angles to the direction of rolling; the others with the grain, or in the direction of the rolling.

Let us now consider the indications here given as to the influence of carbon, manganese, phosphorous, and silicon on the physical qualities of the steel. The average amount of phosphorus is ·039 per cent., and this, I think, will compare favorably with any other steel that has ever been made, taking the number of heats into consideration. The highest phosphorus is found in heats Nos. 551 and 552, where it is ·075; and yet those heats give excellent results. Again, in Nos. 548 and 549, we find ·069 phosphorus, with good results. Conversely, in heats Nos. 605 and 606, we find low phosphorus, ·042 and ·044 per cent. respectively, with results not so good; and still again, in heat No. 499, the phosphorus is only ·031, with results not equal to those first mentioned. We are safe in assuming, therefore, so far as the above tests are concerned, that phosphorus up to the amount of ·075 is not very injurious to the physical properties of soft steel. In all cases in this table where the results are not up to the standard the cause can be directly traced to something else besides phosphorus. In my opinion, phosphorus is not the terrible *bête noir* it has been considered; it has had to bear the burden of many sins wrongfully ascribed to it.

The average amount of carbon is ·15, which I regard as being from ·03 to ·05 too high for the best boiler-plate. The influence of carbon is more certain and regular than that of phosphorus, although there appear to be a few exceptions to the rule that tensile strength increases with carbon. Heat No. 517 has ·22 carbon, with 66,000 tensile strength, while heat No. 530, with ·18 carbon, gives 70,000 tensile strength, with the same amount of manganese in both cases; and heat No. 532, with ·17 carbon and less manganese than the others, gives a still higher tensile strength of 72,000. Again, in heat No. 566, we have ·20 carbon and only 59,600 tensile strength, with a splendid elongation amount-

ing in one case to nearly 31 per cent. These, however, are, I believe, the only exceptions of importance to the rule that tensile strength increases with the amount of carbon; and I will presently suggest an explanation that will account for nearly all the anomalous results.

The average amount of manganese is ·38 per cent. Manganese plays a part similar to carbon, only in a lower degree, and may have comparatively much wider limits of variation than carbon without altering the result. The highest manganese we find in heats Nos. 603 and 503, viz.: ·73 per cent. and ·58 per cent. respectively; and in both cases comparatively high tensile strength and diminished elongation; the carbon in both cases being above the average. There are other cases, however, with manganese above the average, where neither the tensile strength nor the elongation is unduly affected. Heat No. 509 is an example, but it is low in carbon. In heat No. 515, with manganese the same as in No. 509, but with carbon a few points higher, the tensile strength is high again. The lowest manganese is ·17 per cent. in heat No. 453, with the best results; and again, Nos. 538, 544, 557, and 567, showing ·24, ·27, ·29 and ·27 per cent. of manganese respectively, all give excellent results. The manganese, as we would naturally expect, increases or diminishes with the carbon, and the tensile strength in direct proportion to both.

Another point of interest to which I wish to call attention, is the variation of carbon before and after the addition of ferro-manganese. This variation ranges from ·01 per cent. in heat No. 487 to ·10 in No. 617. Assuming that ferro-manganese contains about 5 per cent. of carbon, then the theoretical amount added would be, in a one per cent. charge, just ·05 per cent. It easy to understand that the increase of carbon is sometimes less than ·05 per cent. after the addition of the ferro-manganese, because there is always more or less opportunity for oxidation, but why it should ever be greater than ·05 per cent. is not so easy to understand. I would suggest as an explanation of this abnormal increase of carbon, that a portion of the carbon, before the addition of ferro-manganese, was present as graphite, and that the ferro-manganese caused this graphitic carbon to combine.

The influence of silicon on steel has been but little studied. This has been due to the fact that it is generally present in such small quantities as to make it a question whether or not it has any influence on the physical qualities of the metal.

Silicon prevents carbon from combining with iron. This interesting

fact, although known in a general way by those who have studied the chemistry of pig-iron, was altogether ignored, or lost sight of in steel, until its importance was discovered by Col. Caron. Since then, it has been commented on in Mr. Ward's *Note on the Behavior of Manganese to Carbon*,* and in Mr. Alex. Pourcel's note on the same subject.†

Phosphorus, I believe, acts in a similar manner; for it is a well-known fact that high phosphorus irons will not *chill*, that is, the carbon will not combine with the iron. These facts open up a new line of thought; and I am led to the conclusion that phosphorus and silicon in steel are not hardeners, as heretofore supposed, but are injurious, first, because they have a tendency to keep the carbon in the graphitic state; and second, because they act mechanically (as phosphide and silicide of iron, sometimes, perhaps, as phosphate and silicate of iron) like graphite, to separate the particles of the metal, or in other words, to destroy its continuity or homogeneity. In fact, when we come to think of it as a question of molecular physics, it is difficult to conceive how they could ever have been regarded as hardeners. I am led to this conclusion not only by the results that I have obtained, but also by a study of Dr. Dudley's chemical and physical tests of rails.‡ This is such an important point that I may be excused for citing a few examples from Dr. Dudley's tables.

No. 911 with ·618 per cent. of carbon and 1·044 per cent. of manganese gives 69,000 tensile strength, while No. 906, with less than one half the amounts of carbon and manganese (·308 per cent. and ·462 per cent. respectively) gives the same tensile strength. Now there are only three hypotheses by which we can account for the tensile strength being the same, with such vastly different chemical compositions; we may suppose, first, that the carbon is not all combined; or, second, that the steel contains varying amounts of oxide of iron; or, third, that both these causes are combined. If the carbon in either of the above cases had been all combined (leaving out of the question, at present, oxide of iron), then it is evident that the tensile strength would not only have differed, but would have been much higher in both cases. No. 911 would have shown about 100,000 pounds, and No. 906 about 80,000 pounds. And if it should be found that the carbon

* Transactions, vol. x, p. 268.
† Transactions, vol. xi, p. 197.
‡ Transactions, vol. ix, p. 320.

was all combined, then the low tensile strength of No. 911 must be due to the presence of oxide of iron.

If the above conclusion be true, it follows as a corollary that wear is not so much a question of hardness or softness, as of homogeneity. At all events this theory will account for nearly all Dr. Dudley's anomalous results. It explains why rails from 80,000 to 90,000 tensile strength, are good (see Dudley's tables, Nos. 885 and 917), and why softer rails, from 54,000 to 69,000, are bad (see same tables Nos. 903 and 923.)

It confirms Dr. Dudley's general conclusions, though not for the same reasons. While on this subject, I may say that I agree with Mr. Pourcel, that a high manganese rail may show better wear than a low one, but not for the same reason as he gives. The manganese by removing oxide of iron, and counteracting the effect of silicon and phosphorus, in other words causing the carbon to combine, performs a valuable function in thus rendering the metal homogeneous; but if the same effect could be produced without any manganese being present, I maintain that the steel would be still better. Manganese, *per se*, is a hard, brittle metal, and there is no reason to suppose that when alloyed with iron its qualities change, and that it imparts only hardness without brittleness.

Unfortunately I have not been able to make any graphite or total carbon determinations except in heat No. 612, which I was led to examine more thoroughly chemically, on account of the phenomenal way it behaved in the furnace. It contains, besides the ·16 per cent. of combined carbon, ·15 per cent. of graphite carbon, and ·014 per cent. silicon. Of course I do not mean to contend that ·014 per cent. of silicon will account for ·15 per cent. of graphite; but be that as it may, the graphite is there, and produces the effect we would naturally expect. With a tensile strength of about 63,000 pounds, we only get 23·5 per cent. of elongation; whereas, with the tensile strength as low as that, other things being equal, we ought to get about 28 per cent. elongation. The pig-iron used in this heat (about 15 per cent. of the total charge), was a very high-silicon No. 1 pig; and the test-piece, after the heat was melted and ready for the ferro-manganese, instead of being tough, was as brittle as if the carbon had been ·5 per cent. or ·6 per cent. It was kept in the furnace three hours longer than the usual time (about 6 hours), and doctored with iron-ore and blooms, and finally cast with the above results. In this case the determination

of carbon by either the combustion or the colorimetric method alone, would not give the desired information.

The methods employed for chemical analysis were, for carbon, the color-test, dissolving a standard every time; for phosphorus, the molybdate method, weighing the yellow precipitate; for manganese, the modification of Ford's method, by dissolving in acid proto-sulphate of iron the binoxide precipitated from nitric acid solution by chlorate of potash, and titrating with permanganate of potash. The latter method, when carefully worked, I regard as the most accurate method of determining manganese.

To return to the physical tests: the next point worthy of consideration, is the relation of reduction of area to tensile strength and elongation. Steel may give a high percentage of elongation, with a comparatively low percentage of reduction of area, like the second tests of Nos. 611 and 644; or it may give a low percentage of elongation, with a comparatively high percentage of reduction of area, like Nos. 466 and 490. But the material that I regard as being best adapted for boilers, is that in which both the elongation and the reduction of area are high; say, from 28 per cent. to 30 per cent. elongation, and from 56 per cent. to 60 per cent. reduction of area. The reduction of area should be, and generally is, in an 8-inch section, just double the elongation. When they are both low, the tensile strength is apt to be high, and the quality inferior.

It is to be regretted that we could not anneal the test-pieces without annealing the plates, as this would have removed all variations in the results, due to differences of mechanical treatment, and perhaps would have prevented anomalous results. So much has been written on the treatment of steel, that it would be out of place for me in this paper, to do more than mention in a general way that many of the failures which manufacturers experience with steel plates, are due to the improper manner in which they handle them. Moreover, it is certain that steel plates, after having been flanged and punched, ought to be annealed; for even if they do stand without cracking the severe handling which they receive, they go into the boiler in a state of strain or tension that is dangerous.

The 5th test of No. 464 has been inserted to show what different results can be obtained with the same metal under different treatment. This test was taken from a plate made for the centre-keelson of the *Dolphin*. It was a difficult plate to make, being about 40 feet long,

5 feet wide, and nearly half an inch thick, and was finished at a black heat, giving results as shown in the table. When, however, a test-piece from the same plate was annealed, the trouble was immediately remedied, and the test gave 64,000 tensile strength and over 25 per cent. elongation.

Finally, I wish to call the attention of the Institute to what I consider the most important point developed by these tests, viz., the necessity of having some uniformity in the methods of making physical tests. When we read of a piece of metal having a tensile strength of 60,000 lbs., and a ductility of 25 per cent., we should know just what these figures mean. With the present methods of testing, they may mean much or little. Let standard test-pieces be established and specifications be made, based on such standards. Moreover, unless the conditions under which the tests are made are precisely uniform, no two tests can be compared with each other; for not only do the size and shape of test-pieces affect the results, but also the time, manner of applying the loads, duration of stresses, etc., etc. I give below a few tests, showing the different results obtained under different conditions.

The first test shows the effect of different thicknesses of the same metal.

Dimensions.	Tensile Strength.	Elongation in 8 inches.
·762 x ·7 inches.	52,600 pounds.	30·8 per cent.
1·25 x ·36 "	57,200 "	29·68 "

In this case, by diminishing the thickness of the plate from ·7 to ·36 inches, we increase the tensile strength 4,600 lbs. These differences are still more marked and astonishing if we break test-pieces of different sections from 1 inch to 8 inches. Whether the loads be applied rapidly or slowly, also makes a difference.

Section.	Dimensions.	Tensile Strength.	Elongation.	
1 inch.	·624 x ·602 inch.	75,000 pounds.		
8 "	·8 x ·605 "	65,600 "	23·8 per cent.	across grain.
1 "	·633 x ·591 "	73,500 "		
8 "	·8 x ·588 "	65,800 "	22·8 per cent.	with grain.

The above tests were all carefully made on steel furnished for boiler-plate by a well-known manufacturer in this country. Again with our steel:

	Section.	Tensile Strength.	Red. of Area.	Elongation.
A.	1 inch.	67,300 pounds.	58 per cent.	34 per cent.
A.	8 "	58,000 "	65 per cent.	25 per cent.
B.	1 "	69,700 "	46 per cent.	31 per cent.
B.	8 "	57,000 "	58 per cent.	27 per cent.

Here we have a difference in the case of B of nearly 13,000 lbs. Besides the difference in section, however, the pieces of 1 inch section were all pulled fast; that is to say, no appreciable interval was allowed between the application of the loads as in the 8-inch sections. It would be easy to multiply such examples; but I think it must be evident from the above that the consumer might as well not make any specifications, unless he prescribes all the conditions of testing, viz., thickness of plate, size of test-piece, shape of test-piece, amount of load, duration of stresses, etc. In view of these facts, and the time, trouble, and expense of making so many physical tests, I believe the day is not far distant when chemical specifications alone will be prescribed. Indeed, it is quite possible now to recognize good or bad steel by its chemical analysis: and if some one will only give us a method for determining oxide of iron, it could be done with certainty every time. Chemical methods are becoming more rapid and accurate every day. Combined carbon can now be determined in five minutes and manganese in one hour, and with a previous knowledge of the stock from which the steel is made, there is little more to be desired.

It gives me great pleasure to acknowledge the valuable services of my assistants, Mr. Josef Westesson, who made most of the chemical analyses, and Mr. Loudon Richards, who had charge of the physical tests.

Heat No.	Dimensions of test piece.	Area.	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking.	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese.	Carbon.	Phosphorus.	Manganese.
	Inches.	Sq. in.	Sq. in.	Inches.	In.	lbs.	lbs.	p. ct.	p. ct.				
453	1.125 x .35	.3937	.12	8	10.186	20,870	53,010	69	27.4		.10	.036	.17
464	1.12 x .59	.6628	.2962	8	10.156	43,350	65,405	55.3	26.95		.19	.039	.37
464	.936 x .703	.6580	.3049	8	10.19	43,500	66,100	53.6	27.38				
464	.985 x .695	.6846	.3115	8	10.09	47,200	68,940	54.5	26.12				
464	.967 x .715	.6914	.2934	8	10.017	45,250	65,300	57.7	25.21				
464	1.24 x .455	.5642	.3056	8	9.58	40,000	70,900	45.8	19.7	rol	led	cold.	
465	1.245 x .482	.60	.2511	8	10.254	36,600	61,000	58.	28.2				
*465	1.25 x .482	.6025	.3199	8	9.978	36,000	59,580	53.	24.74		.13	.035	.38
466	.96 x .586	.5625	.2935	8	9.934	41,300	73,300	47.8	24.2		.20	.030	.37
*466	1.127 x .442	.5149	.27	8	9.63	36,000	69,916	57.2	20.37				
467	.928 x .57	.529	.2412	8	9.895	36,390	68,790	54.	23.7				
*467	.984 x .579	.5697	.3125	8	10.206	39,330	69,000	47.	27.82				
468	1.02 x .285	.2907	.1417	8	9.675	19,160	65,910	48.	20.93				
469	.975 x .448	.4368	.196	8	10.12	27,500	62,900	55.	26.5				
*469	1.264 x .6	.7584	.3656	8	10.026	46,500	61,313	51.7	25.32				
470	.921 x .569	.5240	.2501	8	10.383	34,100	65,000	62.	29.8				
*470	.989 x .575	.5686	.2956	8	9.9	36,400	64,000	50.	23.7				
471	1.01 x .454	.4585	.1891	8	10.161	26,000	56,600	58.7	27.01				
*471	1.25 x .595	.7437	.3471	8	9.875	46,540	62,600	53.	23.44				
472	1. x .46	.46	.1925	8	10.17	27,700	60,130	58.	26.13				
*472	1. x .463	.463	.232	8	9.942	27,600	59,600	50.	24.28				
473	1.3 x .438	.5694	.2571	8	10.25	33,950	59,600	54.8	28.13				
*473	1.035 x .55	.5692	.2142	8	10.262	33,700	59,200	62.5	28.15				
474	1.155 x .576	.6653	.2508	8	10.469	36,800	55,300	62.	30.86				
475	.985 x .488	.4806	.1965	8	10.04	27,700	57,630	59.1	30.				
*475	.985 x .484	.4767	.1885	8	10.32	27,550	57,790	56.2	29.				
476	.94 x .5	.47	.165	8	10.255	24,900	53,000	64.8	28.25				
477	1.235 x .441	.5446	.261	8	10.29	31,900	58,500	52.1	28.63				
*477	1.261 x .441	.5561	.2594	8	10.31	32,150	57,800	53.1	28.88				
478	1. x .615	.615	.255	8	10.408	34,200	55,600	58.5	30.1				
479	.999 x .529	.5284	.206	8	10.138	29,300	55,400	61.	26.98				
480	1.028 x .56	.5756	.261	8	10.375	34,000	59,000	56.3	29.68				
*480	1. x .564	.564	.2968	8	10.289	32,400	57,400	47.3	28.61				
481	1. x .475	.475	.2131	8	10.244	26,300	55,790	55.	28.05		.11		.36
482	1.266 x .495	.6266	.3035	8	10.143	40,000	63,836	51.5	26.79	.18	.20		.38
*482	1.266 x .504	.6380	.3633	8	9.68	41,000	64,500	43.	21.				
483	1.225 x .485	.5941	.2455	8	10.208	32,800	55,200	58.7	27.60	.09	.11		.36
484	1.205 x .418	.5036	.2728	8	9.882	35,800	71,000	45.8	23.52	.15	.21		.40
*484	1.254 x .44	.5517	.3451	8	9.688	39,100	79,860	37.4	21.1				
485	1.25 x .507	.6337	.252	8	10.272	35,000	55,200	60.2	28.4	.09	.11		.34
486	1.135 x .50	.5675	.2730	8	10.275	36,130	63,665	51.8	28.4	.10	.12		.37
*486	1.24 x .513	.6361	.3648	8	9.78	39,100	61,400	42.6	22.25				
487	1.19 x .575	.6842	.2788	8	10.17	41,150	60,143	59.25	27.25	.14	.15		.37
*487	1.249 x .586	.7219	.3356	8	10.084	44,000	60,950	53.5	26.05				
488	1.25 x .525	.6562	.264	8	10.545	36,800	56,080	59.9	31.81	.10	.14		.39
489	1.072 x .472	.5059	.2385	8	9.875	30,000	59,300	52.8	24.68	.09	.13		.40
*489	1.246 x .481	.5993	.2557	8	10.025	35,300	59,280	57.9	25.31				
490	1.187 x .339	.4023	.1842	8	9.66	29,600	73,500	54.2	20.75	.16	.21		.56
491	1.264 x .408	.514	.2053	8	10.016	32,900	64,000	60.	25.2	.13	.17		.50
*491	1.262 x .411	.5186	.2491	8	10.046	32,700	63,000	51.9	25.59				
492	1.256 x .292	.3677	.1516	8	10.	23,650	64,310	57.	25.	.09	.13		.49
*492	1.265 x .293	.3706	.1780	8	10.264	23,650	63,860	51.9	28.3				
493	1.26 x .509	.6413	.3521	8	9.983	44,000	68,600	45.	24.78	.14	.16		.53
*493	1.254 x .361	.4527	.2055	8	10.025	30,000	66,290	54.6	25.31				
494	1.217 x .39	.4746	.2187	8	9.959	31,300	65,900	53.9	24.48	.10	.16		.50
*494	1.25 x .387	.4837	.2269	8	10.029	31,900	65,900	53.	25.36				
495	1.25 x .342	.4275	.1938	8	9.970	26,300	61,500	54.7	24.62	.09	.13	.062	.49
*495	1.25 x .348	.4351	.2229	8	10.045	26,000	59,700	46.4	25.6				
496	1.25 x .275	.3437	.1828	8	9.435	23,460	67,660	46.8	17.87	.11	.15	.046	.50
497	1.254 x .296	.3701	.1702	8	9.96	23,300	62,900	54.	24.5	.09	.13		.46
*497	1.25 x .315	.3937	.1896	8	9.854	25,300	64,700	49.3	23.1				
498	1. x .47	.47	.2142	8	9.912	30,000	64,000	54.4	23.9	.12	.16	.058	.49
498	1. x .475	.475	.2338	8	10.025	31,800	66,900	50.8	25.2				
499	1.25 x .285	.3562		8	10.	23,950	67,300	52.3	25.	.09	.15	.031	.50
499	1.25 x .298	.3725		8	9.945	25,300	67,900	53.4	24.31				
500	1. x .5	.5		8	10.256	31,500	63,100	55.2	28.2	.11	.15		.49
500	1. x .5	.5		8	10.144	31,600	63,200	55.3	26.8				
501	1.23 x .327	.4022		8	9.98	26,290	66,630	47.4	24.75	.11	.14		.56
501	1.2 x .321	.3852		8	10.128	24,900	64,640	50.	26.6				
502	1.237 x .37	.4576		8	10.048	28,450	62,200	52.3	25.6	.11	.15		.50
502	1.237 x .37	.4576		8	10.048	29,100	63,500	52.	25.6				

Heat No.	Dimensions of test piece.	Area	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking.	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese.	Carbon.	Phosphorus.	Manganese.
	Inches.	Sq.in.	Sq.in.	Inches.	In.	lbs.	lbs.	p. ct.	p. ct.				
503	1.25 x .432	.5400	.2994	8	10.008	39,700	73,600	44.5	25.1	.15	.17		.58
503	1. x .49	.49	.2599	8	9.955	34,450	70,300	49.	24.44				
503	.98 x .455	.4459	.2050	8	9.9	31,700	71,000	54.	23.75				
503	1. x .455	.455	.2117	8	9.864	32,700	71,860	53.4	23.3				
503	1.25 x .43	.5375	.2949	8	9.861	39,600	73,600	45.1	23.26				
504	.992 x .484	.4801	.2304	8	10.112	30,800	64,100	52.	26.4	.09	.17		.45
504	1.007 x .484	.4873		8	9.875	31,350	64,300	52.9	23.43				
505	1. x .453	.453	.1845	8	10.333	28,000	61,800	59.2	29.1	.09	.15		.39
505	.97 x .462	.4481	.2016	8	10.085	27,500	61,600	55.	26.06				
506	.975 x .485	.4728	.1961	8	10.164	29,700	62,800	58.5	27.	.08	.14		.43
506	.975 x .485	.4728	.1902	8	10.100	29,200	61,750	59.7	26.31				
507	1.167 x .433	.5053	.2485	8	9.911	33,000	65,300	50.8	23.88	.10	.15		.54
507	1.242 x .425	.5278	.2682	3	10.06	35,000	66,310	49.2	25.83				
508	1.25 x .472	.59	.3058	8	10.225	37,000	62,700	48.1	27.8	.11	.14		.49
508	1.25 x .478	.5975	.2765	8	10.062	37,400	62,400	53.7	25.77				
509	1.25 x .46	.575	.261	8	10.275	35,400	61,560	54.6	28.43	.08	.12		.53
509	1.25 x .456	.57	.2781	8	9.937	36,000	63,000	51.2	24.21				
510	1.25 x .463	.5787	.2579	8	9.965	35,700	61,960	55.4	24.6	.08	.15		.47
510	1.245 x .465	.5785	.2566	8	10.165	36,000	62,100	55.6	27.6				
511	1. x .467	.467	.2277	8	9 97	28,800	61,600	51.2	24.63	.07	.15		.48
511	1. x .478	.478	.2156	8	10.284	29,000	60,700	54.9	28.55				
512	1. x .485	.485	.2205	8	10 08	31,300	64,530	54.5	26.	.13	.16		.48
512	1. x .489	.489	.228	8	9.848	31,500	64,400	53.1	23.1				
513	.99 x .464	.4593	.2044	8	10 120	28,450	61,000	55.4	26.5	.09	.14		.47
513	.982 x .46	.4517	.1995	8	10.075	27,500	60,800	55.8	25.9				
514	.983 x .45	.4423	.1883	8	9.796	27,800	62,800	57.8	22.45	.12	.15		.40
514	.983 x .435	.4276	.1969	8	9.960	27,150	63,900	53.9	24.5				
515	1.242 x .385	.4781	.2405	8	9 975	32,600	68,100	49.6	24.7	.12	.16		.53
515	1.23 x .38	.4674	.2484	8	9.975	31,900	68,200	47.	24.7				
516	1.233 x .48	.5918	.2555	8	10.115	37,400	63,000	56.8	26.43	.10	.16		.43
516	1.225 x .475	.5818	.258	8	10.145	37,200	63,900	55.5	26.81				
517	1.25 x .455	.5687	.2634	8	9.927	37,400	65,750	53.6	24.08	.17	.22		.43
517	1.243 x .441	.5481	.2714	8	9.872	36,400	66,400	50.4	23.4				
518	1.254 x .404	.5066	.2312	8	10.	34,000	67,100	58.7	25.	.15	.19		.43
518	1.25 x .404	.505	.2320	8	10.	33,900	67,100	54.	25.				
519	.964 x .44	.4242	.21	8	10.133	27,200	64,100	50.5	26.6	.13	.18		.49
519	.972 x .435	.4228	.198	8	9.892	27,850	65,800	52.9	23.67				
520	.969 x .69	.6685	.3368	8	9.885	41,850	62,600	49.4	23.6	.12	.15		.46
520	.985 x .685	.6747	.3334	8	10.209	41,600	61,600	49.8	27.6				
521	.962 x .722	.6945	.3307	8	10.16	44,250	63,700	52.3	27.	.11	.14		.44
521	.988 x .460	.4545	.1918	8	10.17	29,500	64,000	57.8	27.1				
522	.981 x .686	.6730	.2903	8	9.986	43,900	65,200	55.3	24.8	.12	.16		.46
522	.985 x .688	.6775	.3588	8	9.82	46,200	68,200	47.	22.75				
523	.995 x .707	.7034	.2979	8	10.116	43,750	62,200	57.6	26.45	.09	.14		.38
523	.997 x .711	.7088	.3106	8	10.272	43,280	61,080	54.6	28.4				
524	.985 x .71	.6993	.3471	8	10.	42,900	61,300	50.3	26.25	.10	.14		.39
524	.988 x .71	.7015	.3118	8	10.161	42,800	61,000	55.5	27.01				
525	1.24 x .531	.6584		8	9.718	44,800	68,000		21.47	.12	.16		.46
525	1.25 x .527	.6587	.3672	8	9.762	42,800	64,900	44 3	22.02				
526	.967 x .705	.6817	.3299	8	9.84	41,000	60,120	51.6	23.	.08	.14		.46
526	.963 x .698	.6721	.3230	8	10.117	40,750	60,620	51.9	26.46				
527	.967 x .706	.6827	.3503	8	9.995	43,650	63,930	48.6	24.93	.12	.14		.41
527	.985 x .705	.6944	.3431	8	9.855	43,500	62,640	50.5	23.18				
528	.997 x .708	.7059	.3501	8	10.063	52,500	74,370	50.4	25.78	.15	.21		.46
528	.989 x .709	.7012	.36	8	9.825	52,400	74,700	48.6	22.81				
529	.983 x .700	.6881	.3272	8	10.018	43,000	62,480	51.	25.22	.10	.16		.40
529	1. x .695	.695	.3371	8	10.085	43,350	62,370	51.5	26.06				
530	.985 x .703	.6924	.343	8	9.9	48,000	69,300	50.	23.75	.18	.18		.43
530	.98 x .700	.686	.3127	8	9.8	48,100	70,000	54 4	22.5				
531	.995 x .575	.5721	.3013	8	9.875	38,500	67,290	47.3	23.43	.12	.16		.35
531	.998 x .577	.5758	.2815	8	10.136	37,000	64,200	51.1	26.7				
532	.978 x .554	.5418	.2874	8	9.875	38,950	71,900	46.9	23.43	.13	.17		.35
532	.985 x .555	.5466	.2893	8	9.785	37,850	69,240	48.5	23.37				
533	.975 x .832	.7912	.3630	8	10.10	47,700	60,260	54.	26.25	.11	.14		.30
533	.983 x .837	.8227	.3169	8	10.38	47,200	57,370	61.5	29.75				
534	.975 x .715	.6971	.2756	8	10.22	40,000	57,370	60.4	27.75	.08	.12		.25
534	.974 x .719	.7003	.2893	8	10.323	40,050	57,180	58.6	29.04				
535	.963 x .712	.6856	.2550	8	10.225	39,000	56,900	62.2	27.81				
536	.95 x .693	.6583	.2634	8	10.333	35,850	54,450	56.5	29.16	.06	.11		.45
536	.865 x .70	.6055	.2408	8	10.25	32,550	53,750	58.5	28.12				
537	1.234 x .375	.4627	.1898	8	10.127	27,900	60,300	58.9	26.83	.09	.11		.36

Heat No.	Dimensions of test piece.	Area.	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking.	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese.	Carbon.	Phosphorus.	Manganese.
	Inches.	Sq.in.	Sq.in.	Inches.	In.	lbs.	lbs.	p. ct.	p. ct.				
537	1.262 x .368	.4644	.2061	8	10.145	28,100	60,720	55.6	26.81				
538	1.277 x .498	.6359	.2378	8	10.5	35,900	56,400	62.6	31.25	.05	.11		.24
538	1.035 x .492	.5092	.1950	8	10.291	28,600	56,100	61.7	28.63				
539	1.216 x .492	.5982	.2407	8	10.2	33,600	56,160	58.	27.5	.07	.14		.33
539	1.036 x .480	.4972	.2044	8	10.10	29,350	59,030	58.8	26.2				
539	1.038 x .475	.4930	.2027	8	10.175	29,260	59,300	58.9	27.4				
540	1.25 x .36	.45	.225	8	10.085	28,000	62,200	50.	25.81	.05	.10		.31
540	1.312 x .356	.4671	.2339	8	9.875	28,850	61,900	49.9	23.43				
541	1.210 x .344	.4162	.1877	8	9.96	25,200	60,250	54.9	24.5	.04	.13		.29
541	1.25 x .345	.4312	.1870	8	10.05	26,000	60,296	56.6	25.62				
542	1.210 x .375	.4537	.2231	8	10.15	27,450	60,500	50.8	26.87	.05	.14		.26
542	1.25 x .370	.4625	.1991	8	10.332	27,900	60,320	50.5	29.15				
543	1.205 x .410	.4940	.1961	8	10.457	28,260	57,200	60.	30.7	.05	.15		.31
543	1.255 x .416	.5220	.2142	8	10.30	29,850	57,180	58.9	28.75				
544	1.210 x .463	.5602	.2422	8	10.40	30,800	54,899	56.7	30.	.06	.14		.27
545	1.261 x .335	.4224	.1833	8	10.267	23,100	54,690	56.	28.33	.06	.13	.061	.32
546	1.271 x .398	.5058	.2129	8	10.187	29,500	58,300	57.9	27.3	.09	.14	.057	.29
546	1.263 x .4	.5052	.2378	8	10.172	29,500	58,300	52.9	27.15				
547	1.256 x .432	.5425	.2111	8	10.512	31,000	57,100	61.	31.4	.06	.15	.058	.30
547	1.262 x .428	.5401	.2013	8	10.425	31,200	57,800	62.	30.3				
548	1.258 x .35	.4403	.1871	8	10.405	25,800	58,600	57.5	30.	.10	.16	.069	.27
548	1.243 x .357	.4437	.1744	8	10.288	26,500	59,700	60.6	28.6				
549	1.204 x .445	.5257	.2320	8	10.20	33,300	63,300	55.8	27.5	.08	.19	.069	.34
549	1.032 x .443	.4571	.1952	8	10.23	28,950	63,300	57.2	27.93				
550	1.260 x .325	.4095	.1952	8	10.245	26,700	65,200	50.	28.06	.05	.15	.064	.40
550	1.255 x .34	.4267	.1913	8	10.310	26,700	62,570	55.	28.87				
551	1.250 x .432	.5400	.2119	8	10.50	29,650	54,900	60.7	31.25	.04	.11	.075	.28
552	1.148 x .415	.4764	.1881	8	10.358	27,550	57,820	56.3	29.47	.04	.13	.075	.30
552	1.165 x .410	.4776	.2093	8	10.225	27,550	57,680	56.2	27.8				
553	1.160 x .370	.4292	.1581	8	10.45	22,400	52,190	62.6	30.6	.04	.11	.051	.25
553	1.115 x .373	.4158	.1548	8	10.36	21,700	52,180	62.8	29.5				
554	1.125 x .415	.4668	.2131	8	10.29	28,100	60,200	54.3	28.6	.06	.16	.062	.42
554	.995 x .417	.4149	.1709	8	10.208	25,150	60,600	58.7	27.6				
555	1.064 x .419	.4458	.1966	8	10.325	26,200	58,800	55.9	29.06	.04	.14	.064	.28
555	1.115 x .392	.4370	.1860	8	10.265	25,900	59,200	57.2	28.2				
556	.750 x .672	.5040	.2371	8	10.385	30,150	59,800	52.9	29.8	.06	.15	.043	.30
556	.773 x .71	.5488	.2202	8	10.275	31,500	57,400	59.8	28 43				
557	.762 x .7	.5334	.2227	8	10.465	28,100	52,600	52.	30.8	.06	.14	.050	.29
557	1.25 x .36	.45	.2117	8	10.375	25,750	57,220	53.7	29.68				
557	1.312 x .37	.4854	.1980	8	10.06	27,650	56,960	57.	25.75				
558	1.25 x .375	.4688	.2612	8	9.875	30,600	65,200	44.3	23.43	.06	.15	.046	.38
558	1.26 x .385	.4851	.2327	8	9.915	29,700	61,000	52.	23.9				
559	1.03 x .346	.3563	.1435	8	10.36	29,500	57,500	59.7	29.5	.07	.16	.052	.27
559	1.015 x .347	.3522	.1396	8	10.25	29,500	28,200	60.	28.1				
560	1.023 x .324	.3314	.1384	8	10.325	29,500	56,400	58.5	29.06	.06	.11	.052	.30
561	1.035 x .485	.5019	.2495	8	10.03	30,500	60,760	50.	25.37	.08	.16	.039	.39
561	1.025 x .482	.494	.2283	8	10.15	29,750	60,220	53.9	26.87				
562	.975 x .47	.4582	.1881	8	10.25	26,400	57,600	58.9	28.10	.09	.16	.050	.28
562	1.005 x .475	.4773	.2006	8	10.40	27,650	57,900	58.	30.				
563	.988 x .462	.4564	.1859	8	10.375	26,150	57,300	59.	29.7	.08	.14	.044	.33
563	1. x .46	.46	.1965	8	10.31	26,300	58,000	57.3	28.9				
564	1.310 x .348	.4559	.2005	8	10.066	26,850	59,100	56.	25.8	.08	.16	.037	.40
564	1.312 x .353	.4631	.1778	8	9.975	26,800	57,900	61.1	24.7				
565	.975 x .538	.5245	.2244	8	10.197	31,350	59,790	57.2	27.46	.12	.18	.038	.39
565	1.005 x .54	.5427	.2401	8	10.343	33,300	61,300	55.7	29.3				
566	.985 x .53	.522	.2145	8	10.219	30,500	58,490	58.9	27.73	.11	.20	.039	.41
566	.975 x .525	.5118	.2168	8	10.468	30,500	59,600	57.4	30.8				
567	1.017 x .53	.539	.2167	8	10.25	31,450	58,350	60.9	28.10	.09	.17	.05	.27
567	1.025 x .537	.5504	.2146	8	10.468	31,600	57,400	61.	30.8				
568	1.028 x .5	.5140	.2289	8	10.25	32,450	63,100	55.4	28.1	.11	.17	.044	.42
568	1.023 x .495	.5064	.2376	8	10.188	30,750	60,700	53.	27.34				
569	1.027 x .368	.3779	.2423	8	9.969	24,900	65,900	41.	24.6	.11	.17	.042	.44
569	1.025 x .350	.3587	.1937	8	9.719	23,900	66,600	46.	21.485				
570	1.016 x .380	.3859	.1704	8	10.375	24,700	64,500	55.8	29.68	.11	.17		.42
570	1.022 x .365	.3730	.1810	8	10.125	23,600	63,200	51.4	26.56				
571	1.028 x .594	.6111	.3433	8	9.72	38,200	62,500	43.8	21.5	.11	.16	.047	.41
571	1.028 x .595	.6116	.3257	8	10.09	38,700	63,300	46.7	26.175				
572	1.034 x .565	.5842	.2772	8	10.47	33,500	57,340	52.5	30.86	.10	.15	.053	.37
572	1.03 x 565	.5819	.2645	8	10.28	34,100	57,800	54.	28.5				
573	1.035 x .7	.7245	.4517	8	10.06	44,400	61,200	37.	25.78	.09	.17	.039	.29
573	1.048 x .7	.7335	.3253	8	10.22	42,250	57,600	55.6	27.1				

Heat No.	Dimensions of test piece.	Area.	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking.	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese.	Carbon.	Phosphorus.	Manganese.
	Inches.	Sq in.	Sq.in.	Inches.	In.	lbs.	lbs	p. ct.	p. ct.				
574	1.023 x .69	.7058	.3045	8	10.312	41,100	58,200	56.8	28.9	.08	.14	.038	.35
574	1.05 x .712	.7476	.2938	8	10.281	41,900	56,000	60.	28.5				
675	.815 x .572	.4661	.1984	8	10.064	28,000	60,000	57.3	25.8	.07	.13	.042	.30
575	.840 x .565	.4746	.1799	8	10.187	27,850	58,700	61.	27.3				
576	.99 x .565	.5594	.2292	8	10.313	34,500	61,700	59.	28.9	.08	.14	.048	.36
576	.975 x .565	.5509	.2338	8	10.	33,600	60,900	58.8	25.				
577	.96 x .56	.5280	.2063	8	10.313	30,300	57,400	60.	28.9	.08	.14	.033	.39
577	.98 x .55	.539	.2010	8	10.56	30,550	56,700	62.	32.				
578	.98 x .552	.5409	.2112	8	10.56	31,300	57,860	60 9	32.		.14	.050	.40
578	.854 x .555	.4739	1776	8	10.28	27,450	57,900	62.	28.5				
579	.788 x .548	.4318	.1805	8	10.187	25,700	59,500	58.1	27.3		.15	.047	.37
579	.8 x .545	.4360	.1830	8	10.25	26,500	60,700	59.	28.1				
580	1.008 x .71	.7157	.2992	8	10.031	43,000	60,000	56.8	25.31	.12	.17	.042	.41
580	.755 x .709	.5353	.2175	8	9 97	32,350	60,430	59.3	24.63				
581	1.065 x .706	.7518	.3249	8	10.531	43,100	57,300	56.6	31.64	.07	.14	.047	.33
581	1.154 x .71	.8193	.3449	8	10.25	48,250	59,800	57.9	28.1				
582	1.115 x .575	.6411	.3097	8	10.56	37,150	57,900	51.6	32	.08	.15	.048	.35
582	1.08 x .57	.6156	.2888	8	10 375	35,600	57,800	51.4	29.68				
583	1.036 x .546	.5556	.2241	8	10.188	31,850	57,300	60.	27.34	.07	.15	.055	.32
583	1.068 x .543	.5799	.2485	8	10 594	32,400	55,910	57.1	32.42				
585	1.252 x .468	.5859	.2651	8	10.316	38,000	64,800	54.5	28.9				
585	1.252 x .465	.5831	.2693	8	9.9	39,300	67,300	53.8	23.7				
586	1.25 x .475	.5937	.2889	8	10.05	35,100	59,120	51.3	25.62	.08	.13	.052	.33
586	1.245 x .47	.5851	.2575	8	20.127	34,800	58,100	55.9	26.6				
587	1.248 x .475	.5932	.2562	8	10.31	34,650	58,400	56.8	28.9	.08	.14	.046	.33
587	1.24 x .47	.5828	.3138	8	10.152	37,000	63,400	44.2	26.9				
588	1.242 x .495	.6148	.225	8	10.072	38,700	62,900	60.	25.9	.12	.16	.048	.43
588	1.252 x .503	.6297	.2912	8	9 953	38,000	60,300	53.7	24.4				
589	1.31 x .475	.6222	.3021	8	9.91	39,900	64,400	51.	23.9	.12	.16	.046	.49
589	1.3 x .471	.6123	.2895	8	10.05	40,040	65,300	52.7	25.6				
590	1.228 x .48	.5894	.2676	8	10.121	36,150	61,300	54.6	26.5	.08	.14	.052	.39
590	1.255 x .488	.6027	.3078	8	9.904	35,750	59,300	48.9	23.8				
591	1.225 x .488	.5978	.3063	8	10.065	39,450	65,900	48.9	25 81			.050	.46
591	1.258 x .49	.6164	.3114	8	10 088	39,150	63,400	49.4	26.1				
592	1.236 x .518	.6402	.3438	8	10.05	42,150	65,800	46.3	25.6	.12	.14	.045	.41
592	1.22 x .519	.6332	.3884	8	10.	41,400	65,380	38.6	25.				
593	1.28 x .505	.6464	.3421	8	10.104	41,150	63,600	47.	26.3	.10	.19	.054	.44
593	1.279 x .503	.6433	.3139	8	10.	39,500	61,400	50.	25.				
594	1.274 x .494	.6194	.3204	8	10.109	38,150	61,500	48.2	26.36	.09	.15	.052	.42
594	1.275 x .490	.6247	.3067	8	10.128	39,750	63,600	50.	26.6				
595	1.26 x .448	.5644	.2441	8	10.25	52,750	57,800	56.7	28.1	.08	.13	.046	.36
595	1.26 x .445	.5607	.2651	8	10.110	53,500	59,700	52.7	26.4				
596	1.215 x .487	.5917	.3122	8	9.97	36,650	61,900	40.7	24.6	.12	.16	.037	.42
596	1.19 x .480	.5722	.3045	8	10.067	37,250	65,000	46.	25.8				
597	1.22 x .471	.5746	.2964	8	9.915	37,500	65,200	48.4	23.93	.12	.17	.056	.36
597	1.225 x .472	.5782	.2816	8	9.878	36,900	63,800	51.	23.5				
598	1.227 x .505	.6196	.2908	8	10.158	36,100	58,200	57.8	26.9	.07	.12	.054	.34
598	1.24 x .498	.6175	.2621	8	10.275	33,950	54,900	57.5	28.4				
600	1.254 x .502	.6295	.3096	8	9.76	41,250	65,300	50.8	22.	.12	.18	.060	.40
600	1.23 x .501	.6162	.3255	8	9.775	41,100	66,600	47.	22.2				
601	1.222 x .485	.5926	.3195	8	10.	38,200	64,400	46.	25.	.13	.18	.048	.37
601	1.225 x .48	.588	.3147	8	10.045	38,300	65,100	46 4	25.5				
603	1.252 x .492	.6169	.3895	8	9.66	43.200	70,000	37.	20.8		.19	.056	.73
603	1.26 x .497	.6262	.3791	8	9.775	43,500	69,400	39.3	22.2				
605	1.12 x .44	.4928	.3066	8	9.89	31,400	63,700	38.	23.6	.11	.17	.044	.50
605	1.25 x .438	.5475	.3240	8	10.02	35,900	65,500	40.8	25.3				
606	1.175 x .509	.598	.3589	8	9.575	38,900	65,000	40.	19.7	.09	.14	.042	.47
607	.769 x .706	.5429	.2971	8	9 92	36,150	66,500	45.2	24.	.09	.15	.048	.29
607	1.245 x .704	.8765	.3595	8	10 075	55,200	63,000	47.4	25.7				
608	1.217 x .512	.6231	.2985	8	10 033	36,700	58,900	52.	25.4		.16	.043	.27
608	1.2 x .506	.6072	.2882	8	10	37,250	61,200	52.	25.				
609	1.21 x .509	.6159	.3311	8	9.875	40,250	65,000	46.2	23.43	.09	.15	.052	.29
610	1.195 x .473	.5652	.2720	8	10 375	37,300	65,900	51.8	29 67	.08	.15	.062	.38
610	1.243 x .476	.5917	.303	8	9.96	37,800	64,000	51.2	24.5				
611	1.179 x .473	.5577	.3027	8	9 841	36,100	64,700	45.7	23.01	.09	.17	.047	.38
611	1.245 x .469	.5839	.3096	8	10.25	38,100	65,000	47.	28.1				
612	1.231 x .486	5983	.3276	8	9.938	37,000	61,890	45.2	24.22		.16	.065	.32
612	1.249 x 484	.6045	.2855	8	9.855	39,500	54,900	52.7	23.2				
613	1.245 x .455	.5665	.3007	8	10.	35,250	62,200	47.	25.	.09	.16	.061	.39
613	1.244 x .458	.5697	.3092	8	9.8	36,300	63,700	44.	22.5				
614	1.238 x .46	.5695	.2866	8	10 312	35,000	61,400	49.6	25.39	.08	.16	.051	.39

Heat No.	Dimensions of test piece.	Area.	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking.	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese.	Carbon.	Phosphorus.	Manganese.
	Inches.	Sq.in.	Sq.in.	Inches.	In.	lbs.	lbs.	p. ct.	p. ct.				
614	1.242 x .458	.5688	.2946	8	10.38	34,500	60,600	48.2	29.7				
615	1.24 x .47	.5828	.2861	8	10.185	36,100	61,900	50.9	27.3	.10	.17	.051	.41
615	1.248 x .473	.5903	.3034	8	10.	37,100	62,800	48.6	25.				
616	1.257 x .5	.6285	.2882	8	10.317	38,750	61,600	54.	28.9	.09	.16	.057	.41
616	1.271 x .5	.6355	.3094	8	9.945	30,750	62,500	51.	24.3				
617	1.255 x .51	.64	.3034	8	10.06	43,400	67,800	47.4	25.75	.10	.20	.066	.39
617	1.270 x .512	.6502	.3492	8	10.06	43,650	67,100	46.3	25.75				
618	1.27 x .513	.6515	.3718	8	9.84	41,850	64,000	42.9	23.		.15	.057	.45
618	1.25 x .513	.6412	.3864	8	9.88	45,000	70,000	39.7	23.5				
619	1.26 x .548	.6905	.380	8	10.225	43,850	63,500	42.	27.8		.16	.059	.36
619	1.266 x .552	.6988	.4610	8	9.955	43,750	62,600	34.	24.3				
620	1.252 x .497	.6222	.3208	8	9.848	44,900	72,300	48.4	23.1				
620	1.255 x .5	.6275	.3686	8	9.880	46,500	74,000	41.	23.5				
621	1.248 x .545	.6802	.3285	8	10.025	42,400	62,300	51.8	25.3		.15	.048	.36
621	1.245 x .54	.6723	.3321	8	9.955	42,500	63,200	50.6	24.4				
622	1.25 x .539	.6737	.3474	8	10.085	42,500	63,000	49.3	26.06		.17	.051	.47
622	1.25 x .540	.675	.3494	8	10.166	43,000	63,700	48.2	27.07				
623	1.244 x .48	.5971	.3188	8	10.103	38,000	63,600	46.6	26.29		.15	.060	.43
623	1.248 x .487	.6077	.3168	8	10.178	38,600	63,000	47.8	27.2				
624	1.248 x .487	.6078	.3226	8	10.150	41,000	67,400	46.9	26.87		.15	.052	.41
624	1.25 x .485	.6062	.3077	8	10.252	42,000	69,000	49.	28.				
625	1.25 x .465	.5812	.2835	8	10.08	38,750	66,200	51.	26.		.16	.061	.38
625	1.27 x .468	.5946	.3178	8	10.02	39,500	66,400	46.5	25.2				
626	1.245 x .465	.5789	.3042	8	9.905	40,300	69,400	47.4	23.8		.19	.045	.33
626	1.26 x .466	.5871	.3174	8	9.92	39,500	67,300	45.9	24.				
627	1.25 x .51	.6375	.3707	8	9.915	45,600	71,500	41.8	33.93		.19	.050	.41
627	1.25 x .512	.640	.36	8	10.12	46,000	71,900	43.3	26.5				
628	1.25 x .498	.6225	.2949	8	10.225	35,250	56,600	52.6	27.81		.12	.053	.36
628	1.25 x .490	.6125	.3063	8	10.	36,500	59,500	50.	25.				
630	1.43 x .525	.6526	.3456	8	9.85	39,250	60,100	47.	23.1		.13	.048	.49
630	.985 x .525	.517	.245	8	9.880	32,300	62,800	52.5	23.5				
631	1.195 x .491	.5867	.3204	8	9.885	37,500	63,900	45.3	23.56		.17	.051	.44
631	1.255 x .490	.6150	.36	8	9.868	38,900	63,200	41.4	23.35				
632	1.192 x .472	.5626	.2958	8	9.895	35,350	63,000	47.	23.7		.14	.052	.34
632	1.196 x .477	.5704	.2907	8	10.28	36,000	63,000	49.	28.5				
633	1 2 x .496	.5952	.2689	8	10.025	35,400	59,400	54.8	25.3		.15	.047	.41
633	1.214 x .494	.5997	.2774	8	10.085	34,700	57,800	53.7	26.				
634	1.209 x .5	.6045	.2992	8	10.06	37,250	61,600	50.5	25.7		.16	.051	.45
634	1.256 x .5	.628	.3240	8	9.95	38,750	61,700	48.4	24.3				
635	1 212 x .487	.5902	.2814	8	10.14	33,300	56,760	52.3	26.7		.13	.056	.36
635	1 2 x .488	.5856	.2797	8	10.055	33,800	57,700	52.2	25.7				
636	1 198 x .480	.5750	.2838	8	9.95	34,150	59,300	50.6	24.37		.15	.051	.39
636	1.2 x .485	.582	.3000	8	9.805	34,600	59,400	48.4	22.57				
637	1.198 x .482	.5774	.2520	8	10.24	30,900	53,500	56.3	28.		.13	.049	31
637	1.198 x .480	.5750	.2860	8	10.006	30,900	52,000	50.2	27.5				
638	1.252 x .53	.6636	.3591	8	9.925	43,600	65,700	45.8	24.06		.14	.049	.39
638	1.257 x .531	.6674	.4075	8	9.882	44,500	66,600	38.8	23.5				
639	1.245 x .523	.6511	.3139	8	10.05	37,300	57,280	51.7	25.6		.13	.05	.36
639	1.25 x .523	.6537	.3201	8	10.24	37,700	57,600	51.3	28.				
640	1.255 x .49	.6149	.3132	8	10.235	36,000	58,400	49.	27.8		.13	.049	.30
640	1.26 x .49	.6174	.2975	8	10.268	36,850	59,600	51.8	28.3				
641	1.284 x .49	.6291	.2932	8	10.01	39,500	62,700	46.6	25.		.14	.054	.42
641	1.270 x .5	.6350	.3319	8	10.075	40,500	63,700	47.7	25.9				
642	1.260 x .493	.6212	.2924	8	10.168	35,500	57,100	52.9	27.		.12	.047	.24
642	1.285 x .49	.6296	.2768	8	10.212	35,700	56,700	56.	27.6				
643	1.297 x .485	.6290	.3052	8	10.388	38,500	61,000	51.5	29.8		.15	.040	.30
643	1.270 x .485	.616	.2892	8	10.175	37,700	61,200	53.	27.				
644	1.254 x .498	.6245	.3095	8	9.875	37,700	60,300	50.4	23.4		.15	.055	.41
644	1.272 x .5	.6350	.3305	8	10.38	39,700	60,900	48.	29.7				
645	1.235 x .504	.6224	.3053	8	10.25	36,500	58,600	50.7	28.1		.13	.061	.33
645	1.232 x .505	.6221	.3273	8	10.21	35,900	57,700	47.3	27.6				
646	1.241 x .497	.6167	.3141	8	10.186	37,000	60,000	49.	27.3		.15	.050	.33
646	1.245 x .5	.6225	.3293	8	10.005	36,500	58,600	47.	25.				
647	1.240 x .454	.5629	.2998	8	10.046	33,300	59,100	46.7	25.5		.12	.048	.38
647	1.245 x .454	.5652	.2868	8	10.163	33,200	58,600	52.8	27.				

TO TELL IRON FROM STEEL, IN SMALL PIECES.

Translated from Dingler's *Polytechnisches Journal.* By W. F. Worthington, U. S. N.

A new fracture ordinarily furnishes the means for classifying test pieces, but its appearance is not a sufficiently safe guide in dealing with good, fine-grained iron or very soft steel.

In order to effect the separation with ease and certainty in such cases, Walrand has given a simple method, page 531, "Proceedings of the Société des Ingénieurs Civils," Paris, 1883. It is by observing the fracture of the test piece after heating and allowing it to take a blue color.

The trial can be conducted in the following manner:

Take a test piece about twenty-five or thirty centimeters long and make a slight scratch about four or five centimeters from the end. Then heat one end slowly and uniformly to a dark red color (325° to 400°C.), and cool it in water. During the cooling, while the piece is still warm, it must be rubbed with a file from time to time, until the shining metallic surface laid bare, has assumed a dark yellow, or better, a blue color, when it is to be cooled quickly and completely.

The fractures of the piece broken at the mark, serve for comparison. Ordinary wrought-iron broken when cold appears fibrous or crystalline; but treated as above, its fracture is dull, irregular, and of short fibre. Hard and moderately hard steel are fine grained; after the heating and subsequent treatment, they have a shining, totally or partially, smooth fracture. Sweedish iron has only traces of fibres and is hardly to be told from soft steel; after treatment, the fibres become distinct, the smooth appearance is lost, and the iron becomes so much the more distinguishable from soft steel treated in the same manner.

Marsaut's Safety Lamp.—Museler's lamp has been hitherto thought to be perfectly safe in any explosive mixture of gases where there are no currents, but recent experiments seem to show that an explosion can be produced in from 1 to 5 times per hundred. This discovery explain the accident at Champagnac. Marsaut has accordingly added a second sieve within the horizontal diaphragm, and his new model has resisted more than 6,000 trials, under conditions in which all other forms have been found defective.—*Soc. des Ing. Siv.*, April, 1883. C.

REPORT ON THE TRIAL OF THE "CITY OF FALL RIVER."

By J. E. SAGUE, M. E., and J. B. ADGER, M. E., with an introduction by Professor R. H. THURSTON.

[Introduction by R. H. THURSTON: During the winter of 1882–1883 the writer became interested in the designs of a steamer, then in course of construction by Messrs. W. & A. Fletcher, of New York City, in which were embodied devices which had never before, to his knowledge, been seen in combination. The vessel was a side-wheel steamer of the general form now familiar to all who are accustomed to travel between New York and the Eastern cities on the water routes traversing Long Island Sound. The hull is broad and shallow; the length is moderately large in proportion to breadth, and the lines are tolerably fine. The engines are always of the type introduced by the Messrs. Stevens a half century ago, and still peculiar to American steam navigation—the "beam engine." The propelling instrument is the paddle wheel, and this has, hitherto, always been of the radial type. The engines have always had single cylinders of long stroke, making a moderate number of revolutions, but, in consequence of their length of stroke, having a rather high speed of piston. Their consumption of good coal averages not far from three pounds per hour per horse-power, when furnished with boilers of economical construction. These boilers are, as a rule, of the "return tubular" type, the fire being made in a "fire-box" of rectangular sections, and the gases passing to the "back connection" through flues of moderate size, returning to the fire-box end through tubes of from three to five inches diameter, thence passing up into the "smoke pipe" through a "steam chimney" of sufficient height to dry the steam somewhat before it is sent to the engine.

The plan proposed by the Messrs. Fletcher was a combination of the Redfield boiler, the compound beam engine, and the feathering wheel. The boiler had been built by them before with satisfactory results; the compound beam engine had been constructed many years earlier, from the designs of the late Erastus Smith, a well-known and talented engineer, who has recently died.* The feathering wheel was introduced into this type of vessel as early as 1809—in the *Phœnix*—by Mr. Stevens, who also, many years later, used the same device on the steamer *Stockton*, but it had never been attempted to combine all these well known devices in one vessel. This the builders of the *City of Fall River* were proposing to do.

After consultation between the constructors and the writer, it was determined to make a careful trial of the boat, after its completion, to determine the gain actually realized by the introduction of the devices above mentioned, and the writer was authorized to see the work properly done. The

* The first compound engines are, however, said to have been built by an engineer of a still earlier generation, Mr. J. P. Allaire.

results, if they should prove as favorable to the builders as was anticipated, were to be put in a form satisfactory to them and to the writer, and the latter was to see them put in proper form for publication.

The work of determining the efficiency was finally entrusted to Messrs. Sague and Adger, who had shown great interest in this matter, and who were known to be fully competent to do all that was likely to be required of them. The several trials were, therefore, made by them, under the orders of the writer, and the report was prepared by them, unassisted, and presented to the writer in the early summer of the present year, in the form of a graduating "thesis" at the Stevens Institute of Technology. It will be seen, on examination of the report, however, that it is not to be considered as the work of mere novices, in engineering of this character. Both of its authors had been fortunate in having a considerable previous experience in this kind of work, and both had proven themselves thoroughly expert. The report itself is the best evidence that the confidence placed in them was not misplaced.

The *City of Fall River* was not placed on the route until the spring trade had fairly commenced, and the consequence was that no time could be spared to take the boat off the route for any special preparation for these trials, and the engineers in charge of the work were compelled to do it under some difficulties. The trials were necessarily made at night, and involved, not only some very trying and difficult work, but a continual strain which, together with loss of sleep, combined to make the task one of no ordinary magnitude. The production of so complete a set of data, under the circumstances, is somewhat remarkable, and is not often paralleled.

The results, as given in the report, are extremely interesting, and seem to the writer to fully justify the judgment of the builders in determining to adopt this novel combination.

As will be seen, the fuel used is but about four-sevenths as much as is commonly demanded by steamers of this class, and the weight of good coal per horse-power and per hour is brought down to two pounds, where three and a half would have been expected. The boat makes her trips with great regularity in all weathers, and is vastly less impeded by a heavy sea than even much larger vessels having the radial wheel. The fastest time from dock to dock, ten hours twenty-two minutes, is very remarkable for so small a craft, and the speed attained in the face of a heavy blow is still more extraordinary.

The success of the boat is thoroughly complete, so far as can be judged by experience to date.

The work of measuring the quantity of feed used by the engines was greatly facilitated by the use of the Worthington meters, and the firm of H. R. Worthington & Co. is entitled to especial acknowledgment for the interest taken in the procurement and adjustment of the meters, and for their care in standardizing them before and after the trials. Appended to the report is a summary of all work done to date, including the later figures obtained by the W. & A. Fletcher Co.]

Hoboken, N. J., November, 1883.

INTRODUCTION.

The new freight steamer, *City of Fall River*, now plying between New York City and Fall River, Massachusetts, was built for the Old Colony Steamboat Company, and so designed as to be especially adapted to their trade. The boat required had to combine speed and carrying capacity, and at the same time to be of such form as to admit of rapid loading and unloading. After due consideration of economy and first cost, together with the special demands of the case, it was decided to build a side-wheel boat; and the urgent advice of Mr. S. Taylor, of the W. & A. Fletcher Co., of New York city, overcame all prejudice, and the novel and unprecedented combination of a compound beam engine and feathering paddle-wheels was fixed upon. Our attention was directed by Professor Thurston, of the Stevens Institute of Technology, Hoboken, to the exceptional opportunities afforded in this case for a thorough test of the coal and steam consumption; and this we were enabled to make, at his request, through the liberality of the designer and builders of the engine and the courtesy of the Fall River Line.

The construction of the engine is such as to admit of readily disconnecting the high-pressure cylinder, thus converting it into the simple type of beam-engine common in side-wheel steamers upon American waters, and, after making a thorough test of the compound system, we were enabled to find the steam consumption when working under the latter conditions, which is, we believe, the first time that such a determination has been made with this class of engine.

The object of the present paper is to analyze the performance of each part of the vessel so far as it is separable from the rest, and to compare the results obtained by actual trial with those determined by the best theory.

THE HULL.

The hull of the *City of Fall River* was built by Messrs. Montgomery & Howard, of Chelsea, Mass., from model and specifications prepared by Mr. George Peirce, Superintendent of the Old Colony Steamboat Company. It is of wood, copper-sheathed, and of the best material in every part. The principal dimensions are as follows:

Length on the load water-line	260	feet
Length over all	273	"
Breadth of beam on load water-line	42	"
Breadth of beam over guards	73	"
Depth of hold, molded	18	"
Draught of water, light	9	" 3 in.
Draught of water, loaded 600 tons	12	"
Depth between deck, from top of plank shear to top of upper frame	11	"

The keelson, bilge streaks and beams are of the best Georgia pine. The planking of white oak and yellow pine, and all fastenings are copper and locust-tree nails below the water-line, and galvanized iron and locust-tree nails above. A marked peculiarity is the absence of the usual "hog-frame," its place being supplied by a Howe truss. The upper chord of this truss is two hundred feet long, and supports the deck beams, while the lower chord is bolted to each frame of the vessel. The longitudinal rigidity given by this truss is further increased by a network of diagonal iron straps, fastened behind the clamp-streak to an iron belt plate, and running downwards to the floor timbers. The combination renders the vessel extremely staunch, and even when she is rolling considerably there is not the slightest creaking or straining. The freight space, between decks, is entirely enclosed, and the upper works not extensive; so that the resistance caused by a head wind is not a very serious matter.

DISPLACEMENT.

The principles applied in computing the displacements are to be found in Professor Rankine's "Shipbuilding," Chap. III., Sec. 1, *et seq.* We first computed from the ordinates, which are always half-breadths, the water sections at the various water-lines from the first up to the twelfth or the load water-line. Then taking these water sections as the ordinates of a new curve, upon a base equal to the distance between the load water-line and the lowest water-line, we arrived at the displacements up to each water-line in the series.

The following is the computation of the area of the twelfth water-line section, and will serve to show the process by which all the others were obtained.

The number of cross-sections being 33, the number of intervals was even, and we therefore employed the multipliers given by Simpson's first rule (Mill Work and Machinery, Part II., Art. 289):

No. cross section.	Ordinate.			Multiplier.	Product.		
	Ft.	In.	8ths.		Ft.	In.	8ths.
1	3	6	5	4	14	2	4
2	5	9	7	2	11	7	6
3	8	1	6	4	32	7	0
4	10	4	5	2	20	9	2
5	12	6	0	4	50	0	0
6	14	5	0	2	28	10	0
7	16	1	0	4	64	4	0
8	17	5	1	2	34	10	2
9	18	6	0	4	70	0	0
10	19	4	1	2	38	8	2
11	19	11	5	4	79	10	4
12	20	5	0	2	40	10	0
13	20	8	4	4	82	10	0
14	20	10	5	2	41	9	2
15	20	11	6	4	83	11	0
16	21	0	0	2	42	0	0
17	21	0	0	4	84	0	0
18	21	0	0	2	42	0	0
19	20	11	6	4	83	11	0
20	20	10	5	2	41	9	2
21	20	9	1	4	83	0	4
22	20	6	4	2	41	1	0
23	20	3	2	4	81	1	0
24	19	11	1	2	39	10	2
25	19	5	7	4	77	11	4
26	18	11	4	2	37	11	0
27	18	4	2	4	73	5	0
28	17	7	3	2	35	2	6
29	16	7	1	4	66	4	4
30	15	1	4	2	30	3	0
31	12	10	4	4	51	6	0
32	9	6	2	2	19	0	4
33	4	10	5	4	19	6	4
					3)1649	1	4
					549	8	8

549·708

7·5 = distance between the cross-sections.

4122·81 sq. ft. in half section.

2

82·6245 sq. ft. it 12th water line.

The other water line sections having been obtained by the same process, the sections were taken as ordinates of a new curve; and the number of intervals being even, Simpson's first rule was again applied to obtain the load displacement, as follows:

No. of section.	Area of section.	Multiplier.	Product.
Base.	3426·345	1	3426·345
1	4960·305	4	19841·220
2	5695·300	2	11390·700
3	6023·940	4	24095·760
4	6589·950	2	13179·900
5	6900·195	4	27600·780
6	7150·950	2	14319·900
7	7385·625	4	29542·500
8	7579·050	2	15158·100
9	7760·625	4	31042·500
10	7929·145	2	15858·290
11	8088·225	4	32352·900
12	8245·620	1	8245·620
			3)246054·515
			82018·1716

The interval between the water-lines is 1 foot; therefore we have the displacement equal 82018·1716 cubic feet, and taking 35 cubic feet equal to 1 ton, we have 2343.376 gross tons as the displacement up to the 12th, or load water-line. In this no allowance has been made for the "appendages," but from the data in the hands of the authors, it was estimated that the increase of the displacement at the load water-line due to these appendages would amount to only 7 tons, making a total load displacement of 2,350 gross tons.

In calculating the displacements up to the various other water-lines, the rules given in Rankine's Shipbuilding, (Chap. I, Art. 18 A), were used to obtain the volume between each water-line and the one immediately below it, and this volume was subtracted from the displacement up to the upper line of the two in question. For example, to get the displacement up to the eleventh water-line; to five times the area of the twelfth water-section, add eight times the area of the eleventh water-section and subtract the area of the tenth water-section; multiply the remainder by one-twelfth of the depth of the intermediate layer; the

product will be the volume of the layer; and this volume we subtract from the displacement of the twelfth water-line.

Area of twelfth section	8245·62 × 5 = 41228·10
Area of eleventh section	8088·225 × 8 = 64705·80
	105933·90
Area of tenth section	7929·145
Difference	12)98004·755
Cubic feet.	8167·063

This is now subtracted from the volume displaced up to the twelfth water-line, 82018·172 cubic feet, and the remainder, 73851·109 is the displacement up to the eleventh water-line; or, dividing by 35 cubic feet = one ton, we obtain 2110· gross tons as the eleventh water-line displacement.

In the same way the following displacements were computed for various drafts over the whole possible range for our boat.

Up to the thirteenth water-line	2581·130 gross tons.
Up to the twelfth water-line	2343·376 "
Up to the eleventh water-line	2110·031 "
Up to the tenth water-line	1881·308 "
Up to the ninth water-line	1665·037 "
Up to the eighth water line	1437·518 "

In these figures no allowance is made for the displacement of the appendages.

RESISTANCES.

In Rankine's Shipbuilding (Chap. V, Art. 150 *et seq.*), it is proven that, since a great part of the resistance of the water to the motion of a ship though it is exerted in an indirect manner, the computation of that resistance by a determination of the pressures exerted directly upon the several parts of her immersed surface becomes too complex a problem, and the approximate solution of which he there gives and which is here applied to our case is founded upon the two principles: the *equality of impulse and momentum* and *the equality of energy and work.*

The main causes of resistance are:

The Distortion of the Particles of Water;
The Production of Currents;
The Production of Waves; and
The Production of Frictional Eddies.

The resistance caused by the distortion of the particles of water is, Rankine says, inappreciable in the case of an actual ship, on account of the comparative slowness with which the distortion takes place, while it does become an important factor in the case of models.

The resistance due to the production of currents never acts upon a well designed ship; the form of which enables the particles of water to glide over the whole length, and then be left behind without retaining any appreciable motion.

The production of waves, up to a certain limit of speed does not cause a sensible amount of resistance, though beyond this limit the resistance increases very rapidly with the speed. Thus, according to Rankine, we have only to consider the resistance due to the production of frictional eddies.

This is due to the combined direct and indirect adhesion of the particles of water to the skin of the ship, which, together with the stiffness of the water, produces an infinite number of small whirls or eddies in the layer immediately adjoining the ship's surface. The velocity of the whirling particles bears some fixed proportion to that with which the particles glide over the surface of the ship. The actual energy, therefore, of the whirling motion imparted to a given mass of water at the expense of the propelling power of the ship, is proportional to the square of the velocity of gliding, *i. e.*, to the height due the velocity of gliding.

The velocity of gliding of the particles of water over a given portion of the ship's surface bears a ratio to the speed of the ship, depending on its figure, and the position of the portion of the surface in question; and the height due to the velocity of the gliding is equal to the height due to the speed of the ship multiplied by the square of this ratio. Further, the mass of water upon which whirling motion is impressed by a given portion of the ship's skin, while she advances through a unit's distance, is proportional to the area of that part of the skin multiplied by the above-mentioned ratio. Hence the resistance to the motion of the ship, due to fractional eddies by a given portion of her skin is the product of the following factors:

I. The area of the portion of the ship's skin in question.

II. The cube of the ratio which the velocity of gliding of the particles of water over that area bears to the speed of the ship.

III. The height due to the ship's speed, *i.e.* [speed in knots]$^2 \div 22{\cdot}6$.

IV. The heaviness of water [64 lbs. per cubic foot], and,

V. A factor called the *coefficient of friction*, depending on the material with which the ship's skin is coated and its condition as to roughness or smoothness.

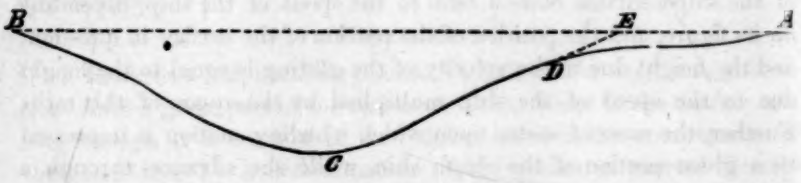
The sum of the products of Factors I, II, and III for the whole surface of the ship is called by Rankine, from whom this is taken, the *augmented surface.*

The resistance due to the formation of eddies may, therefore, be expressed in algebraic symbols, as follows:

$$\text{Eddy resistance} = f\,w\,\frac{C^2}{2g}\int q^2 ds.$$

in which $\int q^2 ds$ is the augmented surface, C is the speed of the ship, g is gravity, w is the heaviness of water, and f is a coefficient of friction, which, according to Weisbach (Rankine's "Shipbuilding," Chap. V., Art. 157), is for surfaces of clean painted iron, $f = \cdot 0036$. Rankine uses this figure for iron ships, and says that the proper one for copper-sheathing is less, but that its exact value is not known.

The computation of the exact augmented surface would be a very complex and almost impracticable problem, and again an approximation must be resorted to. In Rankine's "Shipbuilding" (Chap. V, Art. 162) we find that the method pursued is to assume a figure nearly approximating to the real form of the ship. The figure chosen by him is the trochoid, and the following the formula employed:



The augmented surface is equal to the product of—

I. The length of the ship upon the plane of flotation, which corresponds to the length $A\ B$ of the trochoidal riband.

II. The *mean immersed girth*, found from the body plan as will be shown farther on, corresponding to the total breadth of the riband.

III. A *coefficient of augmentation*, deduced as follows:

The coefficient of augmentation for a trochoidal riband is

$1 + 4$ [sin. of greatest obliquity]^2 + [sin. of greatest obliquity]^4,

the greatest obliquity meaning the greatest angle *B E D* made by a tangent *D E* to the riband at its point of contrary flexure *D* with its straight chord *A B*. For a ship the coefficient of augmentation is the mean of the above coefficients as deduced from the greatest angles of obliquity of the series of water-lines of the forebody, shown on the half breadth plan.

For the *City of Fall River* the following measurements were made, and the coefficients of augmentation obtained:

Number of Water-line.	Actual Measurement.	Sin.	Sin.^{2}	Sin.^{4}
2	5·03	·2515	·0632	·003994
3	4·96	·2480	·0615	·003782
4	5·00	·2500	·0625	·003906
5	5·12	·2560	·0655	·004290
6	5·12	·2560	·0655	·004290
7	5·27	·2635	·0694	·004816
8	5·39	·2695	·0726	·005271
9	5·57	·2785	·0775	·006006
10	5·75	·2875	·0826	·006823
11	5·95	·2975	·0885	·007832
12	6·14	·3070	·0942	·008874

The coefficient of augmentation for

Twelfth water-line	1·272011
Eleventh water-line	1·262603
Tenth	1·253509
Ninth	1·245138

To get the mean immersed girth, a drawing of the body plan, on the scale of $\frac{1}{2}$ inch to 1 foot, was made from the ordinates, and the half girths measured accurately for the 33 cross-sections. The mean value of these half girths was 10·57 inches, which multiplied by 2, on account of the scale, gave 21·14 feet for the value of the mean half girth, and this gave 42·28 feet as the mean immersed girth. This value is the mean immersed girth up to 3 inches above the tenth water-line. The coefficient of augmentation for that draft is 1·2558, and the length of the ship upon that plane is 260 feet; therefore, the *augmented surface* $= 260 \times 42{\cdot}28 \times 1{\cdot}2558 = 13804{\cdot}7$ square feet.

We are now prepared to compare the theoretical probable speed with that actually obtained, or to compute the horse-power theoretically necessary to give a desired speed.

On the double trip, made on the nights of the 9th and 10th of May, the average speed of the *City of Fall River* was 14.54 knots per hour, and the indicated horse-power, as computed from cards taken every half hour during the two runs, was 1616·58. The vessel was immersed on both nights to very nearly the same draft, 10 feet 7 inches, or 3 inches above the tenth water-line, for which draft the coefficient of augmentation has been calculated; 4 inches being allowed for depth of keel.

According to the rule (Rankine's "Shipbuilding," Chap. V, Art. 165), we multiply the indicated horse-power by the coefficient of propulsion, divide the product by the augmented surface, and extract the cube root of this quotient for the *probable speed in knots.*

The coefficient of propulsion established by Rankine for clean iron ships was 20,000, a figure which he arrived at by assuming the proportion of power wasted in the wasteful resistance of the propeller, in slip and through the friction of the engine, to be ·63 of the effective or net power employed in driving the vessel. The coefficient was found by him to be practically exact in a number of cases for iron vessels. He says, however, that, for copper-sheathed vessels, the coefficient of propulsion is unquestionably greater; but how much greater could not then be told owing to the scarcity of experimental data.

Messrs. Elliott & Lieb, of the Class of "80," Stevens Institute of Technology, in some researches in this direction, determined the coefficient of propulsion for copper bottomed vessels to be 23,500, and this coefficient is made use of in the following:

We then have, for the nights of the 9th and 10th of May, the average horse-power 1616·58, multiplied by 23500 equal to 37989630; and dividing this figure by the augmented surface, 13804·7 square feet, we get 2752. We then, according to the rule, extract the cube root of this number, and have as the probable speed 14·02 knots. Subtracting this from the actual speed, 14·54 knots, we have ·52 knots in favor of the vessel.

Again, on the double trip of the nights of the 3d and 4th of May, the actual average of speed obtained was 14·21 knots per hour, while the probable speed, calculated by the above given rule, was 13·96 knots; a difference of ·25 knots, again in favor of the vessel.

In these computations it is assumed that the tide and wind for the two trips balanced; but the error either way might be appreciable. Upon examining the lines of the *City of Fall River* and laying down on the half breadth plan [see dotted lines on the accompanying tracing] the rolling wave line constructed according to the principles stated in Rankine's "Shipbuilding," Part II, Chap. I, Art. 5, it was found that the lines were less sharp than the true trochoid, so that it might be expected that the Rankine theory would not apply exactly, but that the probable speed according to the theory would be greater than that actually obtained. The difference on the opposite side of the scale, as shown above, must therefore be due, either to some error in the coefficient of propulsion, or to the effects of wind and tide. That the latter might have accomplished it is shown by the following facts.

On the night of May 10th, the speed between Point Judith and the Gull Light was noted, and the horse-power of the engine at that time ascertained. From these obvervations the following comparison was obtained:

Actual speed	14·53 knots.
Probable speed	14·03 "
Difference	·50 "

At this time the tide was favorable and the wind hard against the ship. On the same night observations were made at Faulkner's Island and Statford Shoals and the figures obtained were:

Probable speed	14·03 knots.
Actual speed	13·45 "
Difference	·58 "

This difference is on the other side; but at this time the tide and wind were both hard against the ship. It is however the opinion of the authors, formed from information gotten from the pilots, familiar with the route, and from frequent observations during the trips, that in the case of the two double trips quoted above, the tide and wind on the outward and return runs balanced, or if anything were against, rather than for the vessel.

An error in the coefficient of propulsion might be due to the fact that the Morgan Feathering Paddle Wheel is more efficient than the forms of propeller used in the vessels upon whose performance the

above used coefficient was established; and also to some difference in the coefficient of friction for a new copper bottomed boat. These points cannot now be determined without going into a much more extended discussion than the scope of this paper will allow.

PADDLES.

The paddles used are those known as the Morgan Feathering Wheel, and are fitted so as to exert about the same action upon the water as a common radial wheel of twice their diameter. They are of great strength, and are designed especially to withstand the action of ice, which has hitherto been one of the principal impediments to the introduction of feathering wheels in these waters. Each bucket turns upon an axle forming part of the wheel frame; the motion being communicated to it, through arms upon its back, by rods connected to straps upon each side, which revolve about a large journal placed eccentrically to the shaft, and fastened to a truss frame built for the purpose on the guard. The principal dimensions are:

Diameter outside of buckets	25 feet 6 inches.
Number of buckets,	12
Width of each bucket	40 inches.
Length of each bucket	10 feet.
Distance from centre of wheel-shaft to centre of eccentric actuating paddle levers	12 inches.
Length of arm on bucket from axle to lever pin	21 inches.

The feathering thus secured is only approximate; but by laying down the cycloid described by the wheel in going forward through the water, it will be seen, as stated by Rankine,* that the oblique action is too little to be considered in analyzing the efficiency.

Rankine, in treating of the action of propellers in general proceeds as follows.

Every propelling instrument, whether a paddle, screw, or pump, drives a ship by means of the forward reaction of the current which it sends backward. That reaction is transmitted through the propeller to the ship, and, when the vessel moves uniformly, is equal and opposite to her resistance.

(To be continued.)

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* Machinery and mill work.

CORRESPONDENCE.

"THE CHEAPEST POINT OF CUT-OFF."

Editor of the Journal of the Franklin Institute:

SIR:—In the course of a discussion in the JOURNAL, under the title, "The Cheapest Point of Cut-off," I observe that I am accused of heresies, to which I must plead "Not Guilty!"

My views have been entirely misapprehended, as will be seen by reference to papers published long ago in the JOURNAL.

It is said (J. F. I, June, 1884, p. 407) by your contributor, that if he is right, the method of Rankine and the papers of others, including myself, "must be valueless." It is further asserted that other writers, including myself, "have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded." The former accusation is quoted from *The American Engineer*, of 1883, and both have been printed more than once.

I paid no attention to these statements when first published, feeling sure that the writer of these sentences would, in good time, discover and correct the errors. Their repetition makes it necessary for me to correct them for myself. Referring to my papers, already printed in the JOURNAL, it will be seen that, in that of May, 1882, I showed that the "cheapest point of cut-off" was determined by the solution of the "Designer's Problem" enunciated and defined by me thus:

"Given, the quantity of power required, to determine what ratio of expansion, and what size of engine, will give that power at minimum cost." . . . "To solve this problem, the engineer must know the cost of engines, boilers and appurtenances, and all items of running expense. Then, making the sum of both items of variable annual expense—those variable with size of engine and those variable with quantity of steam demanded—a minimum, the sum of those items and of all invariable expenses, *i. e.*, of the total running expense, becomes a minimum, and the problem is solved."

Turning to the enunciation of the same problem, in a later number of the JOURNAL, as given by my critic, I find the following: "The question equally at issue between myself and my critics is this: Do the constant charges have the effect of making the cheapest point of cut-off later than it would appear to be from a purely physical consideration? I have asserted, and believe I have proved, that they do not."

It would appear to me that I had myself anticipated this proof; and I may be permitted to say that my object in writing the paper of May, 1882, to which I have referred for a definition of the problem of the "Cheapest Point of Cut-off," was partly to present such a proof.

With regard to the second statement to which I am compelled to take exception, I need only quote from the same paper to show how far my views differ from those attributed to me, and to prove that I have not "perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded."

There I defined what I have called the "Owner's Problem," which my critic correctly says is that of determining "how to make the best of an existing plant which is not adapted to the requirements of its work," as follows:

"*Given*, the size, power, and all items of cost, and running expenses, of a known plant of steam machinery, to determine what method of working the steam, *i. e.*, what ratio of expansion, will give the most work for a dollar."

Of this case, I remarked that, although the solution determines the ratios of expansion which "give more work for a dollar than the higher ratios" determined by the solution of the first problem, "they do not give maximum efficiency of capital," and go on to state the reason of this fact (Article 14, same paper). The same considerations had been already presented in the same paper, by me (Article 10) thus: "This problem is less frequently presented to the engineer than those already given" (those relating to the first case) "and is not the problem of maximum commercial efficiency; since this ratio, and the corresponding power of the engine, being determined, it will be found, on solving for maximum commercial efficiency, that another proportion of engine, with higher ratio of expansion, will supply the power now demanded at still lower cost. To this latter engine the last problem again applies. The practical conclusion to be drawn from the solution of the interminable succession of problems of this last character, which thus follow the first, is, that the largest amount of power possible should be entrusted to a single engineer, or crew of attendants, and placed under one roof, etc."

I trust that it is not necessary further to discuss this subject, to relieve myself from this misconstruction, and the singularly erroneous charge, to which I have been compelled to reply.

Professor Rankine's enunciation of the first problem is substantially the same as my own. He does not consider the second. His method, in my opinion, is not only not "valueless," but, properly modified to allow for cylinder condensation, becomes supremely valuable.

R. H. THURSTON.

Hoboken, N .J., June, 1884.

Book Notices

TOPOGRAPHICAL SURVEYING, including Topographical Surveying, by Geo. J. Specht, C. E.; New Methods in Topographical Surveying, by Prof. A. S. Hardy; Geometry of Position Applied to Surveying, by John B. McMaster, C. E.; Co-ordinate Surveying, by Henry F. Walling, C. E. Reprinted from Van Nostrand's Magazine. New York: D. Van Nostrand, 1884.

There is much of interest and of use in these four papers, which form No. 72 of Van Nostrand's Science Series. From Mr. Specht's paper, which should have been entitled "Stadia Measurements, and Leveling by Vertical Angles," the student may obtain a fair general idea of the principles and

practice of these methods, and of some of the instruments used in their employment.

The author goes somewhat out of his way to express his disapproval of Mr. Wellington's apparent contempt for contour-line maps. Mr. Specht appears to overlook the fact that Mr. Wellington's strictures are directed to "a contour map *of an ill-judged line.*" No doubt Mr. Wellington would agree with Mr. Specht as to the advantages of a carefully prepared contour map sufficiently extended to embrace *all* the possible lines.

Prof. Hardy's paper, entitled "New Methods in Topographical Surveying," is really an account of photographic topography as practised by the French engineers, notably, Messrs. Laussedat and Ducrot. The use made of the photographic process in Savoy and the Vosges, is referred to as illustrating the saving of time to be effected by its employment.

Mr. McMaster, in his introduction, inspires the reader with his own enthusiasm for the "New Geometry," or "Geometry of Position," which "differs essentially from the Old Geometry, or Geometry of Measure in three particulars: in the simplicity and paucity of its elements, in the total absence of the idea of measure and all metrical relations, and in the great generality and comprehensiveness of its principles and problems." After giving an explanation of the broad principles of the new science, the author illustrates how it may be employed in the solution of surveying problems, such as passing an obstacle, or measuring the distance of an inaccessible point. We fear that, in view of the number of points to be located and borne in mind in employing this method, and the consequent liability to error, most surveyors will prefer the old and apparently simpler methods of laying off three angles of 60°, or four of 90°, in the one case, and of measuring a base line and the two angles at its ends in the other.

As we understand Mr. Walling's paper, it is a suggestion that our states should, with the aid furnished by the government trigonometrical surveys, be divided into rectangles of convenient size, and with sides running north and south and east and west, in order that points may be located by means of their distances north, east, etc. of these lines. The details of the proposed method will, we believe, be found to have been carefully concealed by the author in his descriptions.

Indeed, all of these papers strikingly illustrate the facility with which an author, entirely at home with his subject, may fail to realize that his readers are presumably less familiar with it, and may indulge in technicalities which convey to the uninitiated no satisfactory idea.

The obscurity arising from this inability of the author to put himself in his reader's place, is increased by the topographical errors, which abound throughout the volume, except in the last paper. Some of these are simply amusing, as where we read of the "*total* (instead of *focal*) length of the object glass." "The *largest* (instead of *target*) I use." "Both . . angles are thus determined from the *vicus*" (views), and "The *positions* (positives) thus obtained, though less *distant*" (distinct). Other errors, occurring in the formulæ, are annoying if not insurmountable. For instance, in Mr. Specht's paper, a half-page of equations is made to depend upon the similarity of two dissimilar triangles.

J. C. T.

RECENT LOCOMOTIVES - Illustrations, with Description of Specifications and Details of Recent American and European Locomotives. Reprinted from the Railroad Gazette, 1883. New York: Railroad Gazette.

The work consists of reprints from the *Railroad Gazette*, some of which have been taken from foreign sources.

The first forty-six pages contain descriptions of the engines which are shown in the succeeding plates.

Specifications of the Standard American Locomotive, as built by the Baldwin Works (1877), and by the Grant Works (1873), and of the Mogul Freight Locomotive, as built by the Baldwin Works (1872), are given together with the principal dimensions, and in many cases the weights of the engines shown.

The engines are the principal ones built in the last twelve years, including such as the following, of American build, viz.: Baldwin Standard, Grant Standard, N. Y. C. and H. R. Railroad, Philadelphia and Reading, Pennsylvania, Mogul, Consolidation, Ten- and Twelve-wheel and Tank Locomotives.

Among foreign engines there are a number of English ones, and representatives of France, Sweden, Belgium and Switzerland.

A description and plates are also given of the Fontaine, Fireless, Forney and an English Compound Locomotive, and engines for the Elevated Railroad and for Street Railroads.

Descriptions and cuts are also given of the Wootten and Belpaire fire-boxes, Hill's fire-box door, the water-table used on the N. Y. and H. R. Railroad, Allen's valve, and the double valve used on the Central Pacific road.

The Joy valve gear is shown in detail, as is also the Walschaert gear with the Allen link.

A better selection of engines to represent types could not have been made, had it been the original intention to issue the matter in book form.

The descriptions are for the most part short and to the point, giving the reader the information most generally desired.

The plates are clear and distinct, having in many cases dimensions and sections of the various parts.

The work gives, in a convenient form, much information about locomotive engines and boilers, and should be in the possession of all those interested in the subject.

There is only one criticism to make, and it applies to the majority of works of this class. Having the description in one part of a book and the plates in another makes the use of the book inconvenient. H. W. S.

THE WATCH AND CLOCK MAKER'S HANDBOOK, DICTIONARY AND GUIDE. By F. J. Britten. London: W. Kent & Co.; New York: E. & F. N. Spon, 1884.

Horology has a peculiar charm, and good literature on the subject is welcomed and appreciated by all who are devoted to that branch of applied science. We recognize in this volume a work belonging to this class. However, to review this book would be but to repeat what was said in this JOURNAL, Aug., 1882, about the fourth edition of the "*Watch and Clock*

Maker's Handbook," which was by the same author, and was in substance, with some new matter, identical in contents, but not in arrangement, with the present book.

What makes this volume especially desirable is the manner in which it presents its material. All subjects are given in alphabetical order, which facilitates ready reference to any desired subject, and without loss of time.

The technical terms from the French and German languages are given along with the English, and will be serviceable in many instances where the knowledge of them is needed.

A commendable and pleasing feature of the book is, that it contains short biographical sketches of men who have aided the advancement of horology in any of its branches.

One defect of the book, which it has in common with other works on clock making, is its failure to give to electric clocks a more deserved consideration. This omission is inexcusable in view of the prominence which various systems of time telegraphy have won before the public, and the technical interest involved in their perfection. The bare mention of their existence will not do any longer in a work of this kind. The indications are, at the present time, that the usefulness of the electric clock will have to be demonstrated more through the efforts of the electrician than by those of the experienced clock makers, although the assistance of the latter is much needed. Notwithstanding the prejudice against the new mode of giving the time, and the embarrassments attending the introduction of the electric clock occasioned thereby, it is destined to win a deserved success in the near future.

This defect, however, is one common in all similar works, and it does not detract anything from the excellency of the matter which is contained in this book. L. H. S.

BULLETIN DE LA SOCIETE INTERNATIONALE DES ELECTRICIENS. Tome 1. 1884.

The Committee propose to issue ten or twelve numbers of the *Bulletin* each year, and ask the co-operation of all members of the Society in transmitting documents, which they think will interest the learned or the industrial world, or will help to popularize the knowledge of theoretical electricity and its applications. The subscription price, within the limits of the Postal Union, is 27 francs per annum. The annual fee, for ordinary membership, is 20 francs. The aims of the Society are: 1. To collect information and documents concerning the progress of electricity. 2. To promote the popularization and development of electricity, by writings, publications, and financial aid to successful investigators. 3. To establish and maintain intimate friendly relations among the members. C.

THE PRINCIPLES AND PRACTICE OF ELECTRIC LIGHTING.—By Alvan A. Campbell Swinton. New York: D. Van Nostrand, 1884.

This small octavo volume is not intended to be a treatise for specialists, but rather pretends to fresh and reliable information for the users of electric

lighting and for the general scientific public. It treats of the elementary theory of electric lighting, of mechanical and electrical measurements necessary, of the various sources of power and then of the dynamo electric generators themselves; of the forms of arcs and resistant lamps, secondary batteries, peculiarities of the various electric lighting systems, and finally of the applications of this form of lighting, with its advantages and cost.

The matter is presented in an unpretentious manner, and, what is most gratifying, the descriptions of obsolete and impracticable appliances are omitted. If called upon to recommend a volume for first reading on machinery relating to electric lighting we could scarcely find one so likely to meet the wants of the majority of inquirers. M. B. S.

Franklin Institute.

[*Proceedings of the Stated Meeting, held June* 18, 1884.]

Mr. William P. Tatham in the chair. Present, 179 members and 14 visitors.

The minutes of the May meeting of the INSTITUTE, of the Board of Managers, and of the several standing committees were reported and approved. Thirty-nine (39) persons were elected members at the last meeting of the Board.

On the recommendation of the Board of Managers, the following gentlemen were unanimously elected as honorary members of the Institute:

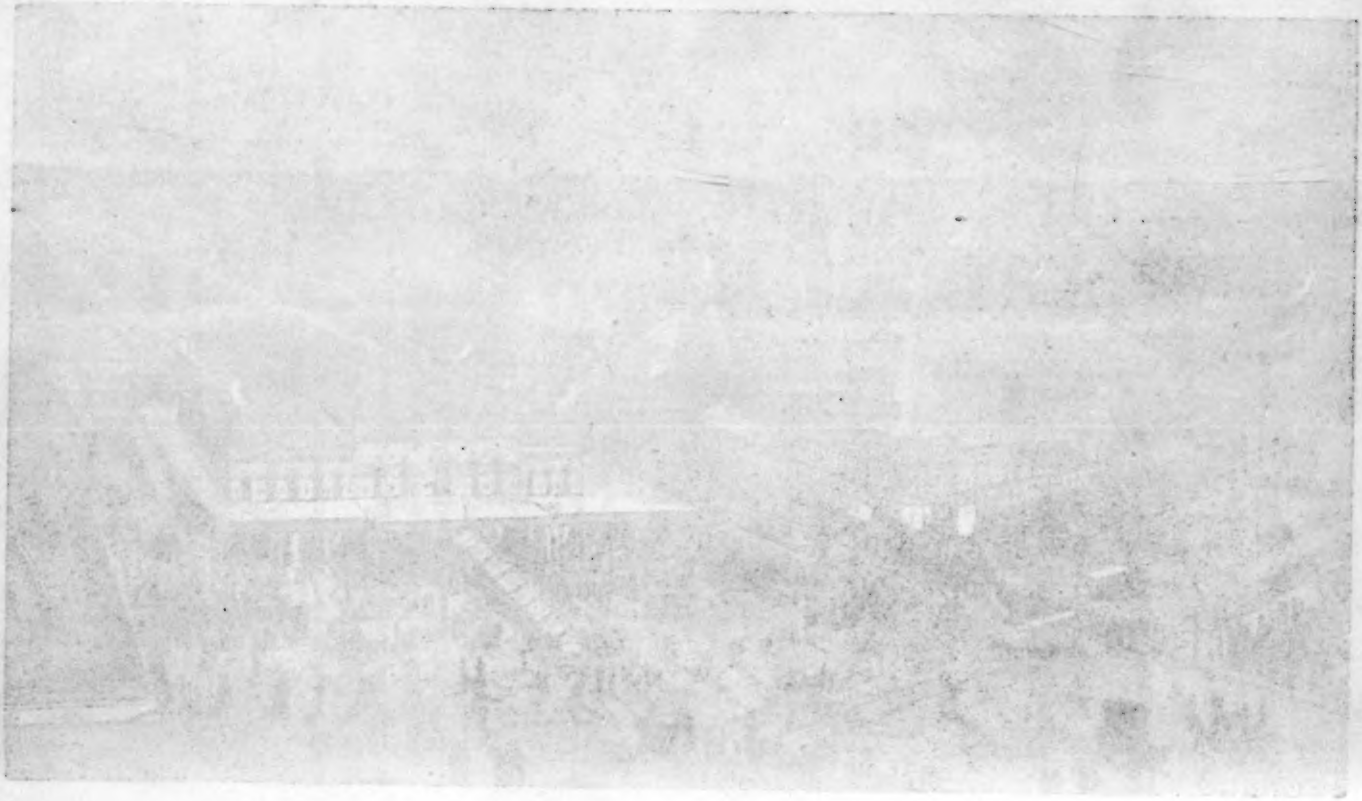
Sir Alexander Grant, Bt., Principal of the University of Edinburgh, 21 Lansdown Crescent, Edinburgh; Professor Thomas C. Archer, Director of the Edinburgh Museum of Science and Art, Edinburgh; Professor William Swan, LL.D., F.R.S.E., Ardachaple, Helensburgh, President of the Royal Scottish Society of Arts; Edward Sang, Esq., LL.D., F.R.S.E., 6 Molendo Terrace, Edinburgh, Secretary of the Royal Scottish Society of Arts.

Mr. Charles J. Quetil read a paper descriptive of a "Triangular Suspension Truss," which he had devised, and which is proposed for elevated railroads, bridges, roofs, viaducts, etc. The paper was discussed by Mr. Hugo Bilgram and the author. It has been referred to the Committee on Publications.

Mr. S. Lloyd Wiegand read a paper explanatory of the phenomena accompanying "Tests by Hydrostatic Pressure." The paper was discussed by Messrs. J. W. Nystrom, Bilgram, and the author. The paper has been referred for publication.

Mr. J. W. Nystrom, described and showed in operation, a magnetic engine of his invention.

The Secretary's report embraced some remarks on the future water supply of the city of Philadelphia, based principally upon the report of Col. William Ludlow, Chief of the Water Department.

Several mechanical inventions were shown and described. Adjourned.

WILLIAM H. WAHL, *Secretary.*